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MareMonstrum: a Contribution to Empirical Research about How the Use of MUVEs May Improve Students' Motivation

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Abstract: The use of Multi-User Virtual Environments (MUVEs) is a trend topic in virtual education and e-learning. A number of research papers and literature reviews addresses how digital natives learn in a different way than the previous generation and how these kinds of highly interactive environments may positively affect their motivation. But actual efficacy of MUVEs to enhance students' motivation has not been deeply backed up yet by empirical research. This paper contributes with a small experiment conducted on an elective programming course for engineering students. The hypothesis was that the use of a MUVE would improve students' motivation towards learning. To evaluate the veracity of this hypothesis, the dropout rates of the course were compared alongside four academic years, assuming that lower dropout rates imply a motivation increase. The first two years (Y1 and Y2) a traditional approach based on lectures, weekly assignments and a final exam was used. The last two years (Y3 and Y4), the NUCLEO approach was used. NUCLEO is a pedagogical strategy that combines game mechanics (including collaboration and competition), problem-based learning and a fantastic narrative metaphor. In Y3 the NUCLEO approach was implemented having a flat classical interface provided by the standard Moodle Learning Management System (LMS), while in Y4 a ·3D MUVE was used as interface. Dropouts during the traditional teaching period (Y1-2) fell dramatically during the NUCLEO teaching period (Y3-4). However, dropouts were higher in Y4 when a MUVE was used as interface (16.66%) compared to Y3 (9.09%). These data suggest that just using a MUVE or a 3D environment can enhance motivation but to achieve maximum effectiveness if they are combined with elements like game mechanics. These data were also backed up by satisfaction questionnaires fulfilled by teachers and students.

Keywords: Computer Supported Collaborative Learning, Problem Based Learning, Learning in Multi-User Virtual Environments
Categories: H.5.1, J.2, L.5.1, L.6.1

1 Introduction

E-learning systems are following the path of modern Internet applications, as the social and communication habits of learners and teachers change. Social networks, Multi-User Virtual Environments (MUVEs), online games and software collaborative tools have opened the door to new possibilities in collaborative learning.

Multi-User Virtual Environments (MUVEs) have been on the educational arena for a number of years. In the past, numerous educational uses of some general-purpose MUVEs were discussed, placing special emphasis on SecondLife^{TM} [Khosrowjerdi et al. 2005; Warburton 2009; deNoyelles and Kyeong-Ju Seo 2012]. Moreover, many virtual worlds have been specifically developed for education, supporting young people in learning a wide domain of subjects. Some of the most cited examples are River City [Squire 2003], Revolution [Aldrich 2003], AquaMoose [Devendorf et al. 2009] or Quest Atlantis [Dede et al. 2005]. Finally, a growing body of research reveals the educational and social potential of virtual worlds [Lim et al. 2006; Mikropoulos and Natsis 2011; Warburton 2009].

The rationale behind many of these use cases was built around the concept of "digital natives" (or millennium learners), a term coined by [Prensky 2001b] and also supported by other authors [Aldrich 2005]. The hypothesis sustained by these authors is that the current generation of youngsters is not attracted anymore to textual, static applications and contents. They have grown playing with videogames, consoles and mobile devices, and using applications that are, above all, immersive and highly interactive. Technology in general and videogames in particular, with their appealing graphical interfaces, have been part of their everyday lives since they were kids. Therefore, they concluded that the formats of educational applications must be adapted to what the digital natives feel more attracted to in order to regain their attention.

MUVEs belong to the genre of applications that respond to these demands. They are immersive, highly interactive and they enable multiple participants to interact and communicate concurrently in a virtual world through “avatars” that they use to represent themselves in the virtual world.

Nevertheless, in spite of the potential of MUVEs for educational purposes, their efficacy in reaching specific learning objectives, compared to other traditional approaches, is still under discussion [Mikropoulos and Natsis 2011], as it also happens with other related learning technologies like game-based learning [Hays 2005; Rice 2007]. Even the motivational aspects that are usually related to MUVEs have not obtained general acceptance within the academic community. Although several experiments have been performed in this concern [Clarke and Dede 2005; Ibáñez et al. 2011b; Mayrath et al. 2011], there is still little contrasted and accepted evidence in the literature to reach a solid and a generally accepted conclusion. This lack of evidence, added to other inconveniences of MUVEs such as high development cost or elevated computer requirements are preventing a more general adoption of educational MUVEs. To clarify these issues, more experimental research is needed.

The conclusions presented in this paper are the result of analyzing the use of two different implementations of the NUCLEO framework (see [Sancho et al. 2009a; Sancho et al. 2009b; Sancho et al. 2009c], for further details about the NUCLEO project). They have been used in several courses that took place over two consecutive academic years for the same module. Both implementations shared the same underlying learning strategy. The main difference is that the first implementation (Mundo NUCLEO) used the *Moodle*^{TM} Learning Management System as a 2D interface. The second one (Mare Monstrum) replaced the 2D user interface with a rich immersive 3D virtual world as user interface (*Multiverse*) using the same underlying learning strategy. *Moodle*^{TM} was still used on the server side, to store all data related to the course (students' progress, assignments, contents, etc.) and to provide server-side services such as groups or forums. However, all data and contents were presented through the MUVE interface (integrated in the fantastic metaphor) and both students and teachers interacted through the MUVE. The goal was to analyze the use of a 3D MUVE as a motivation enhancer.

Summarizing: Mare Monstrum, is an e-learning application based on *Moodle*^{TM} [Dougiamas and Taylor 2003] (a Learning Management System) and *Multiverse* [Boulos L. Hetherington, S. Wheeler 2007] (a MUVE), that was developed under the NUCLEO research project, with the aim of bringing some light to the following question: are MUVEs effective in terms of motivation enhancement? It gives life to a learning strategy, supported by a 3D immersive scenario, which includes game mechanics, a strong narrative, a fantastic metaphor and role play dynamics over an underlying a problem based learning strategy. It also aims to enhance the competition atmosphere by using social recognition strategies.

The paper is structured as follows: First, in Section 2 we provide some related work about MUVEs, game-based learning and their connection to engineering education. In Section 3 we briefly describe the NUCLEO pedagogical framework (which sets the theoretical base for both the Mundo Nucleo and Mare Monstrum systems). After that, we describe the two different implementations of the NUCLEO framework that have been used in this research: Mundo Nucleo (Section 4) and Mare Monstrum (Section 5). Next, in Section 6, we present two case studies that have been performed to test the real impact that different aspects of the NUCLEO approach have on student motivation. In Section 7 we discuss the results obtained. Finally, some conclusions and future work are presented in Section 8.

2 Related Work

As a consequence of the growing interest in the use of MUVEs for teaching and learning, several initiatives are applying general-purpose MUVEs in education in multiple domains (e.g. SecondLife™ [Boulos L. Hetherington, S. Wheeler 2007; Conklin 2007; Kemp et al. 2009; deNoyelles and Kyeong-Ju Seo 2012]). Moreover, many virtual worlds have recently been developed specifically for education [Hou 2012; Ibáñez et al. 2011a; Mayrath et al. 2011; Sykes 2011], thus supporting learning in a wide range of subjects. Most cited examples make intense use of game-based learning strategies to convey better learning experiences. This is the case of systems like River City [Ketelhut et al. 2006], Revolution [Jenkins et al. 2003] or Quest Atlantis [Barab et al. 2005], which are oriented to young people in middle and high school. Other MUVEs have been devised for their application in undergraduate and professional training programs, like AquaMoose [Edwards et al. 2001] or AppEdTech [Tashner et al. 2005]. Finally, a growing body of research reveals the educational and social potential of virtual worlds and game-based learning [Dickey 2010; De Freitas

2006; Gamage et al. 2011]. Experts in the field have also started to consider that these technologies are almost ready to go mainstream. For example, the Horizon report (2012 edition) estimates that game-based learning and collaborative technologies like MUVEs may be ready for widespread adoption in the mid-term (2-3 years) for K-12 education [Johnson et al. 2012].

Digital games and MUVEs have been used also in higher education disciplines like civil engineering [Ebner and Holzinger 2007], digital design [Srinivasan et al. 2008], electronics [Belfore et al. 2009] or language learning [Ibáñez et al. 2011a; Sykes 2011]. Moreover, advocators have discussed the potential of digital games to improve education in STEM disciplines (science, technology, engineering and mathematics), [Mayo 2007; Mayo 2009] by analyzing how features present in games contribute to develop valuable skills in future engineers and scientists (e.g immersive and realistic environments, short feedback cycles, etc.).

Games and MUVEs offer students the chance to face real-world open-ended problems, which is necessary for engineers, as opposite to classical teaching methods where theory predominates over practice (e.g. combining lectures and Computer-Assisted Design tools). In this regard role-play and simulation games where players must run complex businesses or organizations (e.g. VirtualU™ or the Sim™ or Tycoon™ sagas) are especially adequate for the improvement of management skills [Blunt 2007; Chapman and Martin 1995]. For instance, in these games students can play the role of the manager of a manufacturing company and experience the management of the whole product life cycle and how their decisions affect the results of the company. In this manner games and MUVEs with high simulation levels can foster the acquisition of problem solving skills. Another interesting example in this regard is the use of racing games to learn vehicle dynamics in a mechanical engineering course [Hulme et al. 2009]. In addition, the high level of realism achieved by these technologies allow students to increment their laboratory time and rehearse with specific machinery and equipment that are not always available as many times as desired in a cost-effective manner [Campbell et al. 2002].

In addition, in MUVEs students can interact with other peers in a natural way, enabling the implementation of learning strategies that foster the development of teamwork skills. This is one of the most important abilities that future engineers will require. In fact, many of the initiatives that explore the use of new technologies in engineering education focus on the implementation of advanced collaboration features as one of the most important requisites [Hiekata et al. 2008; Ramani et al. 2003].

3 The NUCLEO Project

3.1 Overview

NUCLEO is an instructional framework that pursues three main objectives: (1) to improve students' motivation, (2) to push students towards a more active role in learning, and (3) to help students to develop teamwork abilities and soft skills while they acquire state-of-the-art knowledge and technical skills.

NUCLEO uses a pedagogical approach deeply grounded in the socio-constructive stream, in which students collaborate in small teams to reach the solution of real-world, open-ended, ill-structured problems (lacking of a specific and well defined answer) as they would do in classical problem-based learning scenarios [Neufeld and Barrows 1974]. The whole learning scenario is turned into a game where participants (teachers and students), contents and assignments are immersed in a fantastic virtual world.

From a technology perspective, 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, which simplifies its integration in the educational infrastructure [Del Blanco et al. 2010; Del Blanco et al. 2012].

The overall design of the NUCLEO system is founded on three basic premises, which are the result of a wide study on the state of the art in e-learning and educational systems:

- There seems to be a fairly general consensus about a global decline in student motivation. A corpus of research blames the dull textual content that may simply not attract the attention of a generation of students who are used to more immersive ways of interacting with digital content [Prensky 2001a].
- The labor market is much more demanding today than it used to be just a decade ago. Today's professionals are not only required to have state-of-the-art knowledge, but also to develop social abilities that are essential for teamwork, such as leadership, communication or conflict resolution. Therefore, the educational system should cover these new demands and be adapted consequently.
- E-learning systems, such as Learning Management Systems (e.g. WebCT-Blackboard™, Sakai™ [Farmer and Dolphin 2005], or Moodle™ [Dougiamas and Taylor 2003]) are here to stay. During the past decade, huge inversions in e-learning systems have been sponsored by public and private educational institutions. Many educational organizations are using modern LMS not only for distance or correspondence learning but also as a complement for traditional lectures (an educational trend usually known as blended learning or b-learning). Those LMS 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 or promote communication and collaboration among students (i.e. collaborative learning). In this manner the integration of MUVEs (and educational games) with LMS may push forward the adoption of MUVEs as educational tools.

To increase the cost efficiency and optimize the educational value of our system, we have designed four different phases in order to gradually check different hypotheses. The case studies that are discussed in this paper were developed during phases 1 and 2:

- Phase 0: Documentation and research of pedagogical and technological strategies for e-learning systems in order to define the pedagogical strategy and produce the instructional design of the system. This was purely a documentary phase. In this phase the basic hypotheses were also outlined, as well as the back-story and the game narrative.
- Phase 1: Proof of concept. In this phase we made use of free collaborative-supporting tools for learning environments with a classical 2D UI. The goal was to verify the main pedagogical hypotheses on which the system relies, namely: does the PBL approach embedded in a game metaphor increase student motivation? Is the learning strategy effective in terms of knowledge acquisition? And also, does the collaborative framework help students in practicing soft skills?

- Phase 2: Proof of the effectiveness of the virtual scenario. The main objective of this phase is to verify the impact of several aspects of the 3D virtual scenario and the avatars on students' motivation. The Mare Monstrum prototype was built to support this part of the research.
- Phase 3. Development of the beta system. In this phase a complete system is being developed and distributed for beta testing in different learning contexts. Due to the high development efforts and investment required, we want to redefine certain key functionality features in the previous phases.

3.2 Description of the Learning Strategy

In order to accomplish the aforementioned objectives, NUCLEO uses a Problem-Based Learning (PBL) approach as the underlying pedagogical strategy, where the learning scenario is set in the virtual fantasy world of role play games. It relies on a fantastic narrative metaphor to enhance the motivation of the students, but also on gaming aspects, especially team competition and collaboration.

In NUCLEO 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 it is commonly done in 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.

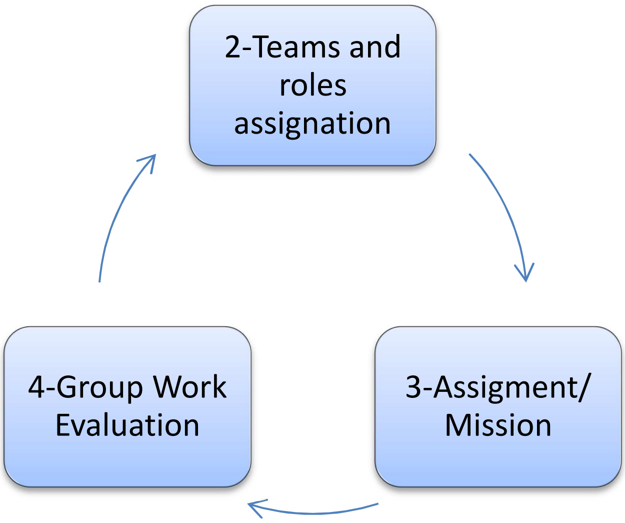


Figure 1: Learning process strategy in Nucleo

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. Students are organized in auto-regulated teams of 3 or 4 students where each individual is assigned a role with specific functions and responsibilities. The adaptation model establishes how the roles are assigned.

Groups of students face "assignments" or “missions” that simulate real danger situations. The final goal is to be awarded with the title of “Paladins” (social recognition), warriors that fight for the survival of the civilization. During these assignments students compete both individually and across teams.

Assignments represent the practical cases of the underlying PBL approach. They are set in the domain of knowledge and are presented embedded in the narrative of the baseline metaphor.

The learning process in Nucleo strategy follows the schema illustrated in Figure 1.

4 Mundo NUCLEO

This first prototype for the *NUCLEO* system (*Mundo NUCLEO*) used the 2D web interface provided by *Moodle*$^{\mathrm{TM}}$. Students and teachers accessed dontent, assignments, communication and collaboration tools through *Moodle*$^{\mathrm{TM}}$. It was developed and tested in three different case studies as a proof of concept for the basic pedagogical hypotheses that underlie the learning strategy. Particularly: does the PBL approach embedded in a game metaphor increase the students’ motivation? Is the learning strategy effective in terms of knowledge acquisition? And also, does the collaborative framework help students in acquiring soft skills?

The game metaphor takes the students to an artificial world called *NUCLEO,* threatened by a computer virus called *La Ciénaga*. In this scenario, they play the role of warriors that have to be trained in the weapons of knowledge to fight against the menace. During the training, they are presented with several missions that simulate real attacks against *La Ciénaga*. To complete these missions, they are clustered in groups which make up the crew of the aircraft of a symbiotic spaceship, and they have to collaborate to get to the optimum solution. The collaboration procedure within a group is specified according to a classical PBL schema and the three members of the aircraft have different responsibilities according to the role they are assigned.

Therefore in *Mundo NUCLEO,* social interaction takes place according to two different schemas (competition and collaboration) and at two different levels (individually and in groups). Competition and collaboration are two of the foundations of our system, as they are two of the team-making mechanics that have proved to boost motivation and to improve group dynamics in different learning contexts [Johnson and Jonhson 1975]. The competitive atmosphere is enhanced by publishing individual and team results, using rankings. The collaboration takes place using web 2.0 collaboration tools.

Even if the educational gain obtained with a game or game-like environment is very difficult to assess and evaluate [Hays 2005], *Mundo NUCLEO* was tested with students and the results obtained were really promising, as we discuss in Section 5. At the same time, the methodology proved to be effective in terms of pure knowledge acquisition, as the marks obtained in the exams for that course were significantly higher than for the previous ones (for a complete analysis of these results see [Sancho et al. 2009b]). Also, the students reported that they found the system useful for the development of soft and teamwork skills [Sancho et al. 2009a].

5 Mare Monstrum

Mare Monstrum is the second prototype developed following the theories of the *NUCLEO* framework. It integrates two existing technologies: *Moodle*™, which is a popular open source LMS, and *Multiverse,* a MUVE (see its reference architecture in see Figure 2

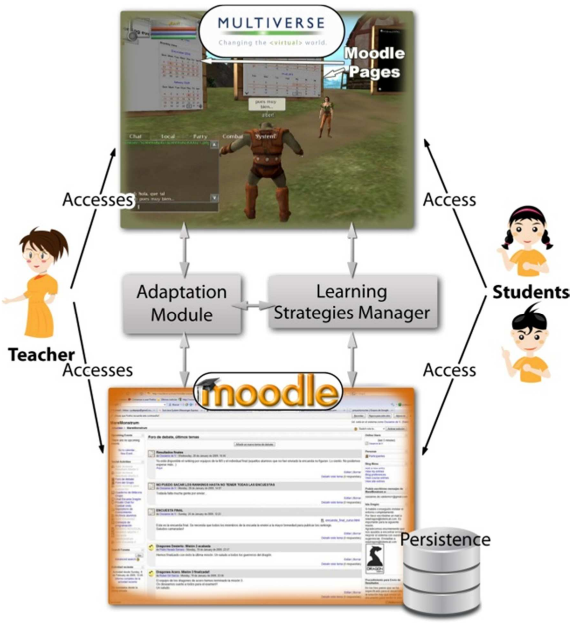
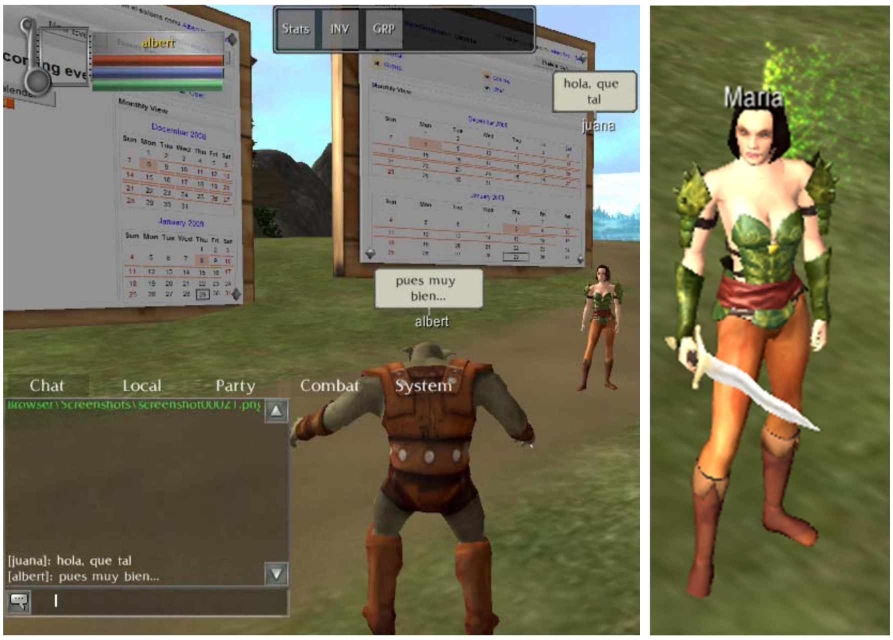


Figure 2: Reference architecture behind Mare Monstrum, which combines a MUVE (Multiverse™) as interface and an LMS (Moodle™) on the server.

It was developed in order to test those hypotheses of the *NUCLEO* project related to the use of an immersive virtual world as a motivation enhancer. It preserves the essence of its predecessor, *Mundo NUCLEO*, with slight modifications:

- The game metaphor has been slightly modified. The environment has been changed to a medieval fantasy aesthetic, while preserving the old schema. We changed the metaphor due to budget reasons: the platform chose for developing the environment included graphs libraries with medieval aesthetics. In *Mare Monstrum* learning takes place on Dragon Island, which is inhabited by the survivors of an ancient civilization, *the Picts*. Again, they are threatened by a terrible enemy, *The Dark Lords*, who want to destroy all knowledge and plunge their world into darkness. *The Sea Dragons*, the last guardians of wisdom, take on the responsibility to train *the Picts* in the weapons of knowledge. Within this metaphoric frame the game simulates a school of warriors competing to achieve the rank of Dragon Warriors. Students play the role of these candidate champions through an avatar, while tutors play the role of *The Sea Dragons*.

The web client interface provided by MoodleTM was replaced by the 3D MUVE Multiverse. MoodleTM was still used at the server side, providing a centralized place to store data (students' profile, assignments, mission status, contents, etc.) and services such as forums or groups. These data and services were accessed through the Multiverse, embedded in the fantastic metaphor (see Figure 3-left). Thus in Mare Monstrum a 3D immersive interface is used to implement the fantastic world, whereas in the previous implementation the fantasy elements where recreated by plain text and static graphics. Also, the students are represented by customizable 3D avatars (characters of the virtual world), while in MundoNucleo students were represented by a simple 2D profile picture.Mare Monstrum supports the competition-collaboration dichotomy by means of two main resources. First, it promotes social recognition through rankings (as it was done in *Mundo NUCLEO*) and rewards students' avatars with physically distinctive characteristics according to the students' achievements (see Figure 3-right).



[juana]: hola, que tal
[albert]: pues muy bien...

Figure 3: Left: Moodle data that is embedded into the fantastic metaphor and presented through the Multiverse interface. Right: A student's avatar that has been awarded a physically distinctive feature (a halo) as a mechanism of social recognition for his/her achievements

Secondly, it addresses the different levels and schemas of social interaction by dividing the virtual world of *Mare Monstrum* into three different zones, with specific tools to facilitate the interaction (see Figure 4):

- *The Pict Village*: area for global interaction. Information panels, such as the mission announcements panel, individual and group rankings, and the public forum are displayed here. These panels are connected directly to the LMS (i.e. *Moodle*), and automatically reflect any change in the MUVE on the permanent record that the LMS stores. All the students have access to this zone, but they can only access the information related to the module they are enrolled in. The course rankings are public for all its members to foster motivation by social recognition (see Figure 4).

- *The Pier*: area for group interaction. A boat on the sea represents a restricted group interaction zone. It is equipped with tools to manage group collaboration, such as private forums, blogs or file sharing facilities (see Figure 4).
- *The Dragon Cliffs*: area for student-tutor interaction. There are two types of facilities at this zone: a zone to send messages to the teacher and a zone in which the tutor can leave additional files for the students (see Figure 4). To force in-game team communication among students in a group only one student per group is allowed to communicate to the teacher. The selection of the interlocutor for each group is done based on the abilities of the students.

All these tools were also present in the previous prototype (*Mundo NUCLEO*), in which they were not represented by a 3D environment, but by using classical 2D web interfaces.

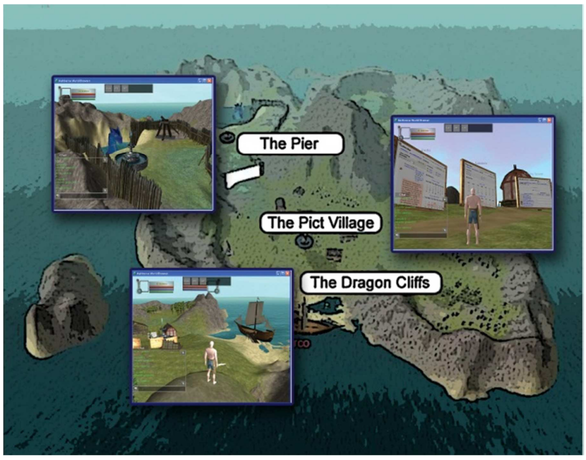


Figure 4: Dragon Island from Mare Monstrum with the three relevant areas: The Pict Village, The Pier and The Dragon Cliffs.

6 Two Case studies of *NUCLEO* Prototypes in Engineering Education

So far, the *NUCLEO* pedagogical approach has been evaluated through two different case studies, (phases 1 and 2 as stated in Section 2).

In the first case study *NUCLEO* was used in a engineering educational context: the module *Programming Fundamentals* (PF) during two academic years (Y3 and Y4). The goal of this case study was to evaluate whether the *NUCLEO* approach was capable of enhancing students' motivation. During the first year (Y3) a group of volunteer students used the first prototype, *Mundo Nucleo* (which did not have a 3D virtual world interface). In the second year (Y4) all the students used the second prototype (*Mare Monstrum*) compulsorily.

In the second case study *Mare Monstrum* was tested by a group of experts and selected users (both teachers and students). The goal was to gather insight about the impact that the next three elements of *Mare Mostrum* have on the student motivation:

- The role-game dynamics of the learning scenario
- The immersive 3D virtual world scenario
- Fostering competition amongst the students (either direct competition using rankings and other strategies or using social recognition strategies).

6.1. First case study: Teaching Programming Fundamentals to Electronic Engineering Students

Programming Fundamentals is an optional module of the Electronic Engineering degree at the Complutense University of Madrid (Spain) that students can take during the first year. In this module students gather general background of software programming (basic concepts of algorithms, design and coding of programs, etc.). The programming language they typically use in this module is C++. Normally in this module a traditional pedagogical approach is followed, combining 2 hours of lectures per week and 3 hours of practical sessions in the computer programming lab. The method to evaluate the learning outcomes of the students in this module takes into account the results of a final test that students must take at the end of the module (60%) and their weekly assignments and participation in class (40%). In order to pass the module students must compulsorily attend the final exam.

Over the last few years, lecturers of PF had observed that dropout rates have increased alarmingly and the grades of the students were going down gradually. This trend suggests a strong decrease in student motivation over the last few years. Therefore the goal of this case study was to test the *NUCLEO* approach in this scenario to analyze if it had a real impact on the motivation of the students.

The indicator used for measuring the evolution of the students' motivation is the average dropout rate, calculated as the percentage of students that did not attend the final exam at the end of the module in comparison to the total number of students that enrolled in the module at the beginning of the term.

Over two academic years before the experiment (Y1, Y2) the lecturers in the module followed the traditional teacher-centered approach. In both academic years the pedagogical approach followed was exactly the same, as well as the lecturers who conducted the module.

In the year Y3 an example group (EG) of 22 volunteers followed the NUCLEO approach, combining traditional sessions (lectures, practical laboratory sessions, etc.) and online sessions using the system *Mundo Nucleo* (2D user interface). For the control group (CG) of 38 students the traditional approach was used (identical to the previous years Y1 and Y2). The students in the EG were released from the obligation to attend the lectures. To interact with other students or with the teacher, they mainly used the virtual world. The evaluation method of the module for the EG took into account both the in-game missions (i.e. assignments) that the students had to solve in *Mundo Nucleo* (40%) and the grade on the final exam (60%).

In the year Y4 the prototype *Mare Monstrum* (3D virtual world interface) was used by all 54 students enrolled in the course. In this case the pedagogical approach was similar to the EG in the year Y3, but some differences applied. The most relevant is that participation was mandatory for all the students, as opposed to the voluntary nature of the experiment in the year Y3.

Table 1 shows the evolution of dropout rates throughout the four year period.

Academic year	**Pedagogical approach**	**Students enrolled (A)**	**Students attending exam (B)**	**Dropouts (C=A-B)**	**Dropout rate (D=C/A%)**
Y1	Traditional	115	43	72	62.61
Y2	Traditional	110	33	77	70
Y3	Traditional	38	13	25	65.79
	NUCLEO (*Mundo NUCLEO*)	22	20	2	9.09
	TOTAL Y3	**60**	**33**	**27**	**45.00**
Y4	*NUCLEO* (*Mare Monstrum*)	54	45	9	16.67

Table 1: Statistical data for dropout rates during the two previous years to the experiment and two years of experiment

In addition, in Y4 students filled in a satisfaction questionnaire on the Likert scale (1= strongly disagree, 2= disagree, 3= agree, 4= strongly agree) to collect their opinion on different issues related to the system. Three questions are relevant to this paper as their purpose was to evaluate the impact that the three aforementioned aspects of the *NUCLEO* approach had on student motivation.

Table 2 shows the results of the survey, merging the percentages of students that agreed and strongly agreed to the questions into one group, and the percentages of students that disagreed or strongly disagreed into a second group.

6.2. Second Case Study: Evaluation by Experts and Selected Users

In the second case study, the *NUCLEO* approach was evaluated by 22 experts (8 teachers and 14 selected students). All the teachers selected (professors of Software Engineering and Artificial Intelligence at the Complutense University of Madrid) were experts in the design and development of e-learning applications and had proven experience in conducting modules of software programming.

	Strongly Disagree (%)	**Disagree (%)**	**Agree (%)**	**Strongly Agree (%)**
1. I think that this learning strategy based on a **game** makes learning more motivating than a traditional, lecture-based strategy	0	4.65	35	60.35
2. I think that using a **3D immersive virtual world** to represent the metaphor of the game makes learning more motivating	10.11	34.08	20.40	35.41
3. I think that **competition** makes learning more motivating	14.80	20.08	20.02	45.10

Table 2: Results of the student satisfaction questionnaire in likert scale

			Students		
	Did not answer the question (%)	Strongly Disagree (%)	Disagree (%)	Agree (%)	Strongly Agree (%)
1. Using a **game** as a learning scenario enhances the motivation of the student	0	0	0	0	100
2. Using a **3D immersive virtual world** enhances the motivation of the student	0	4.20	10.09	31.60	54.11
3.Promoting **competition** among students and groups enhances the motivation of the student	7.14	11.13	10.30	27.06	44.37
4. Linking physically distinctive signs to the achievements of the student as a mechanism of **social recognition** enhances the motivation of the students	7.14	9.03	12.40	38,26	33.17

Table 3: Students' satisfaction questionnaire on the Likert scale for the second case study.

			Teachers		
	Did not answer the question (%)	Strongly Disagree (%)	Disagree (%)	Agree (%)	Strongly Agree (%)
1. Using a **game** as a learning scenario enhances the motivation of the student	0	0	0	10	90
2. Using a **3D immersive virtual world** enhances the motivation of the student	0	10	15	15	60
3.Promoting **competition** among students and groups enhances the motivation of the student	0	2.5	10.0	7.5	80
4. Linking physically distinctive signs to the achievements of the student as a mechanism of **social recognition** enhances the motivation of the students	0	10	15	15	60

Table 4: Teachers' results of the satisfaction questionnaire on the Likert scale for the second case study.

All the students selected claimed to be fond of playing digital games or Massive Multiplayer Online Role Games (MMORG). Both groups (teachers and students) filled out a satisfaction questionnaire after trying the system out during the term. The questions were similar to case study 1 and the results obtained are presented in Table 3 for students and Table 3*: Students' satisfaction questionnaire on the Likert scale for the second case study.* for teachers.

7 Discussion of the results

In the first case study the evolution of dropout rates during the four year period shows that when a traditional approach was followed, the dropout rate average (rate of students that did not attend the final exam in comparison to the number of students enrolled in the course) ranged from 60% to 70%. In Y3, the first prototype (*Mundo Nucleo,* which used a 2D GUI instead of a 3D virtual world) was used by a group of 22 volunteers. While the control group maintained a similar dropout rate (65.79%), the experimental group reduced the dropout rate dramatically, to only 9.09% (see Figure 5). These results might be influenced by the voluntary nature of the experiment, which may have attracted highly-motivated students, and/or by the small number of students enrolled in the module (only 60 students compared to 115 and 110 in the previous years). Nevertheless, in Y4 the use of the second prototype, *Mare Monstrum,* was compulsory for all students and the dropout rate at the end of the course was around 16%. Although this rate is slightly higher than the previous year, it is still a great improvement.

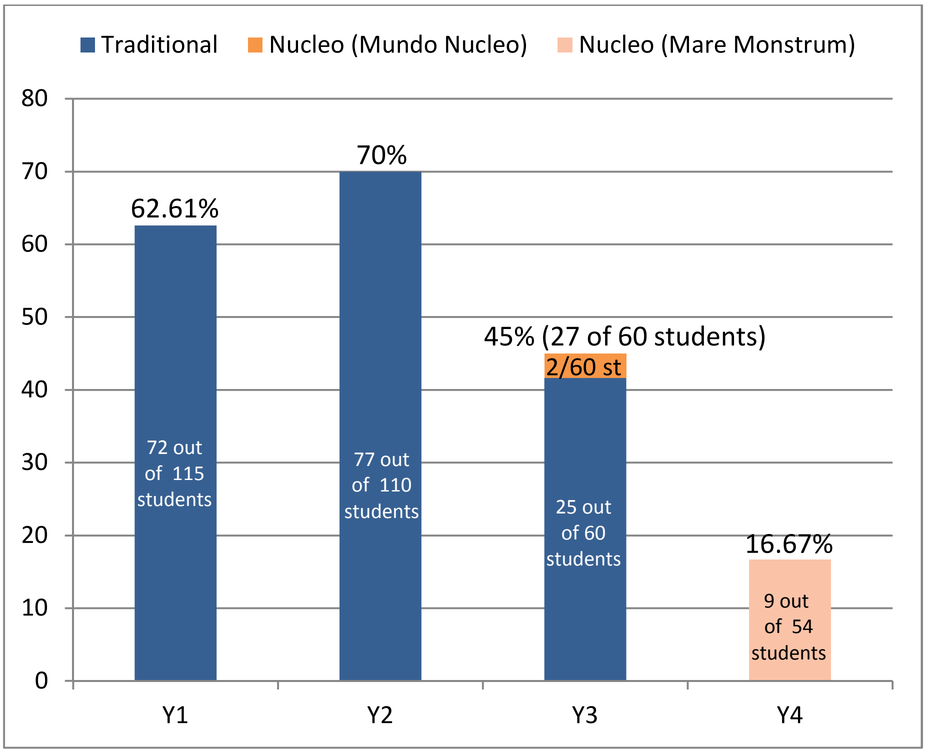


Figure 5: Evolution of the dropout rates over the four year period. In year 3, the chart shows the proportion of .dropouts produced in the traditional group (25 of 27 droputs) and the Mundo Nucleo group (only 2 of the 27 total dropouts this year).

Although cases 1 and 2 have shown the positive influence of the method on improving students motivation,, other factors may have biased the results. For instance, the teacher's attitude may have affected the results, as she might have been more enthusiastic with the new experiment setting. This being a subjective matter, it is impossible to offer quantitative measurements to counter-argue it. However, there are several reasons to support that the impact of the teacher attitude should be minimum, if any. First of all, the teacher did not change, as she has been in charge of the course over the last six years. Besides, her attitude has always been enthusiastic and always adopted an active and constructive role. She has been permanently worried and concerned about improving class dynamics, and tried out some other motivational techniques in previous years, such as plain Problem Based Learning, without obtaining significant results. Also, over the years, she has participated in the official Spanish Innovative Programs for teaching and learning. Finally she always obtained similar results in the students' annual evaluation, no matter what teaching strategy she has used.

Other potential cause of noise in the data is that contact between teacher and students was closer in both NUCLEO approaches, and the feedback cycle shorter, as they had to complete missions scheduled almost every week. However, the number and frequency of assignments was similar when the traditional teaching was used, and the kind and quantity of communication and feedback provided to the students was already high. So, in any case, this factor would have little importance.

Finally, it is unlikely that the decreased dropout rate could be attributed to a less challenging programme for two reasons. On the one hand, the amount and depth of content covered in the module remained the same. On the second hand, in Y3 students in the control and example groups were exposed to the same final exam. Students in the example group outperformed those in the control group [Sancho et al. 2009b].

Even though these arguments can support our conclusions to a certain extent, no doubt an accurate validation of our conclusions would require wider experimentation. As Hays points out, demonstrating the efficacy of games in terms of acquiring knowledge would require extensive research involving a large number of students from diverse disciplines for several years [Hays 2005]. Also in [de Freitas and Oliver 2006] the difficulty of evaluating learning gain in game-based applications is pointed out. Although solving this problem is certainly beyond the reach of our possibilities, the NUCLEO project keeps on and more experiments are being performed to determine the validity of the methodology in the long term.

According to the satisfaction questionnaire after the first case study, 95.35% of the students thought that the role-game dynamics made the course more motivational. Regarding the use of a 3D virtual world as user interface to immerse the learning scenario in a fantasy world, only a slight majority (55.81%) considered that it was positive for motivation. Finally, boosting competition through social recognition strategies was motivating for only 65.12% of the students.

Several conclusions can be inferred from these data. The most relevant is that the most powerful aspect for motivation is the use of game mechanics and strategies in the learning experience, regardless of how the game is presented to the students (using a 3D virtual world interface or a 2D UI). Secondly, it is interesting that the competitive atmosphere does not seem to be important to a considerable number of students (around 35%) in terms of motivation, which suggests that this strategy is not adequate for all the students.

In the second case study the results of the satisfaction survey were separated into two different groups for analysis: students (see Figure 7) and teachers (see Figure 8). The results of this survey are consistent to the first case study. In this case all the students and teachers (100%) agreed on the potential of game mechanics to enhance student motivation. Regarding the competitive atmosphere the results are quite similar in both questionnaires (ranging from 60% to 70% approximately). These findings are coherent with recent research that explored teachers' perceptions about MUVEs in several focus groups [Gamage et al. 2011].

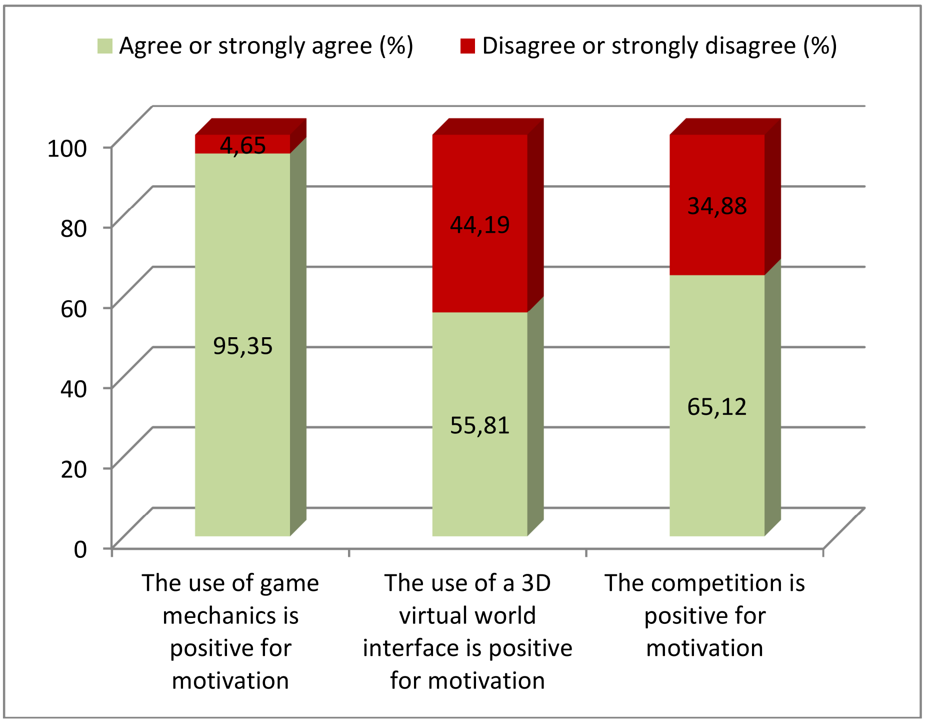


Figure 6: Results of the Likert student satisfaction survey for the first case study

Nonetheless, there is a relevant difference concerning the ability of the 3D virtual world to engage students. In the second case study all the teachers (100%) agree that the 3D virtual world interface is positive for students' motivation, while the percentage of students that think the virtual world is a positive element in terms of motivation rises to 85.71%. This data is much higher than the 55.81% obtained in the first case study. This difference may be related to the fact that the students selected from the second case study were frequent users of MMORGs.

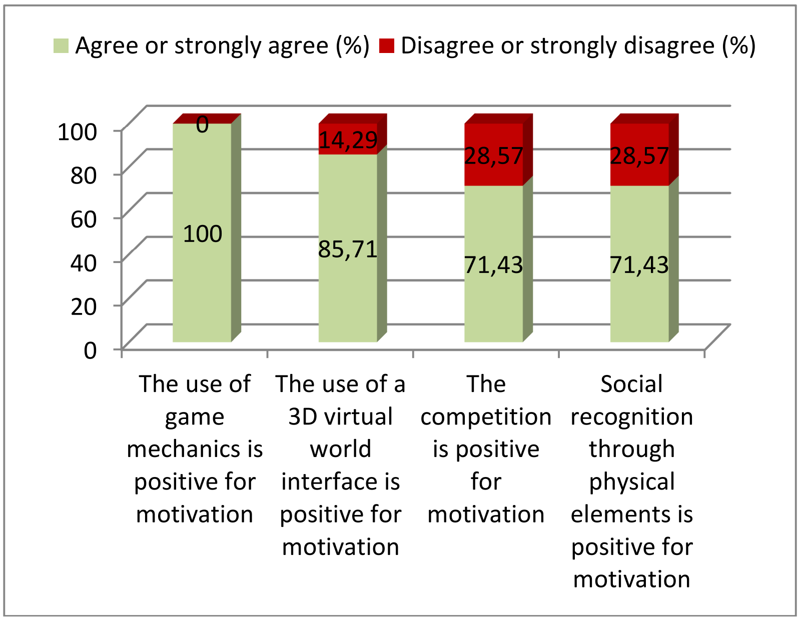


Figure 7: Students' results of the Likert satisfaction survey for the second case study.

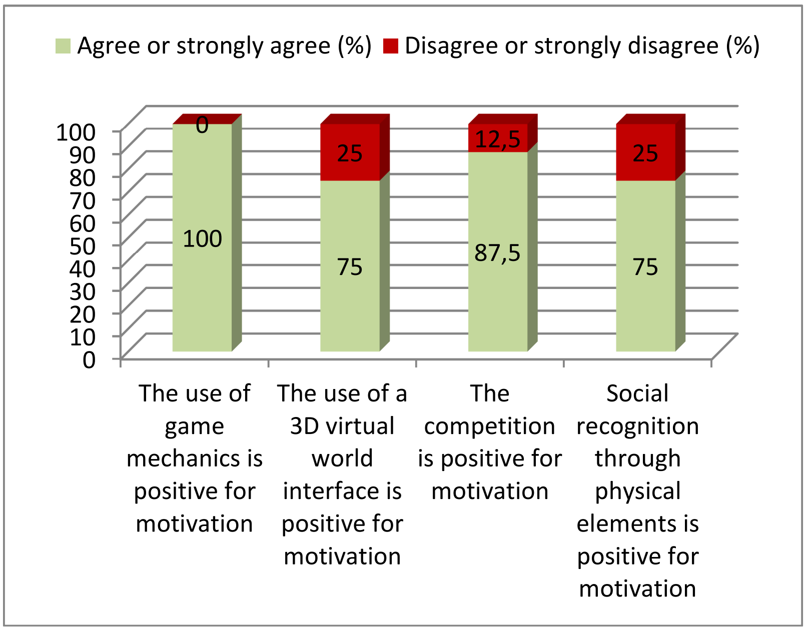


Figure 8: Teachers' results of the Likert satisfaction survey for the second case study.

8 Conclusions and future work

In this paper we have analyzed the impact that MUVEs have on students' motivation. For that purpose, two prototypes of *NUCLEO*, *Mundo Nucleo* and *Mare Monstrum,* were used. Both share the common ideas behind *NUCLEO*, differing only in the nature of the user interface: while *Mundo Nucleo* used a plain 2D interface, *Mare Monstrum* replaced this layer with a 3D immersive virtual world. This allowed us to analyze the effect that this specific feature (the application of a 3D virtual world as user interface) actually causes on the motivation of the students.

Even though this evaluation is just a starting point and more practical research has to be performed in order to infer further conclusions, taking the results obtained in our experiments as a base, we can extract the following conclusions:

- Multi User Virtual Environments can enhance student motivation if they are designed carefully, following a sound pedagogical approach.
- Fantasy and gaming are powerful motivators. But representing them through an immersive 3D multi-user virtual world interface, with powerful graphics, does not seem to be as important as the gaming or the learning strategies themselves.
- Boosting competition by using social recognition strategies works very well for the majority of students while it is counterproductive for a considerable minority. While the causes of this unexpected issue are still uncertain, it is likely that students who do not have a competitive personality perceive this as extra pressure instead of additional motivation.

On the one hand, these are interesting conclusions for educational settings, where educational video games and MUVEs are sometimes rejected by using the arguments of high development costs and top-tier computers these systems usually require, or the complexity of getting these systems installed and running (not all instructors have the appropriate background to deal with this issue). In this concern the results suggest that to design highly motivational video games and MUVEs with educational value the investment does not necessarily have to be focused on the development of powerful technology (e.g. complex 3D graphics, sophisticated Artificial Intelligence, etc.) but on the good design of the underlying gaming and learning strategies. This allows us to avoid the most expensive or system-demanding approaches. Following these indications we could reduce the development costs of educational MUVEs, the complexity of the installation process and remove the requirement to have top-tier computers in the classroom, which would open the range of educational institutions that could adopt this kind of instructional approach. Additionally another interesting conclusion is that, in light of this data it might be necessary to redesign the competitive atmosphere or provide alternatives for those students who do not feel attracted by competition.

On the other hand, in spite of the fact that the case studies described had quite positive results, it is still unclear which part of the results come from the change in the class strategy itself and which comes from the use of the 3D virtual environment. Moreover, it would be necessary to analyze whether the enhancement of motivation that the results suggest is a real consequence of applying the *NUCLEO* pedagogical framework or just the by-product of introducing a novelty into the routine of daily learning dynamics. Nonetheless these results suggest that these immersive environments could be quite appealing for digital native students that are more technologically oriented or for those that are hardcore users of social networks.

Besides, the *NUCLEO* approach should be tested in other engineering environments in order to determine whether the conclusions extracted about the impact on students' motivation are scalable to other disciplines (e.g. product manufacturing, mechanical engineering, etc.). It would not be difficult to produce new instances of the general *NUCLEO* framework apart from the development cost of repurposing the prototypes (*Mundo Nucleo* and *Mare Monstrum*) or implementing new environments, as it is built upon solid educational principles that will fit almost any engineering course. For instance, the Problem-Based Learning approach and the role-playing strategy are easily scalable to other domains, as discussed in Section 2. Besides, cooperative and competitive strategies are two desirable skills that all engineers should acquire. However, embedding an engineering course in the fantasy atmosphere that *NUCLEO* presents is challenging and demands a high level of imagination that not all instructors have.

Next steps in the project are to obtain a more complete MUVE, easier to install, with better teacher support, and to extend its usability to other knowledge domains different from programming courses. In addition, *NUCLEO* will also be applied next years in engineering education scenarios, which will add more data for analysis and further conclusions.

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References

[Aldrich 2003] Aldrich, C.: "Simulations and the Future of Learning: An Innovative (and Perhaps Revolutionary) Approach to e-Learning"; (2003).

[Aldrich 2005] Aldrich, C.: "Learning by Doing: A Comprehensive Guide to Simulations, Computer Games, and Pedagogy in e-Learning and Other Educational Experiences"; Pfeiffer, San Francisco, CA

[Barab et al. 2005] Barab, S., Thomas, A., Dodge, M., Carteaux, R., Tuzun, H.: "Making learning fun: Quest Atlantis, a game without guns"; Educational Technology Research and Development, 53, 1 (2005), 86–108.

[Belfore et al. 2009] Belfore, L.A., Adcock, A.B., Watson, G.S.: "Introducing digital logic and electronics concepts in a game-like environment"; In: International S for CS [ed]San Diego, CA, USA, 1–7

[Blunt 2007] Blunt, R.: "Does Game-Based Learning Work? Results from Three Recent Studies";

[Boulos L. Hetherington, S. Wheeler 2007] Boulos L. Hetherington, S. Wheeler, M.N.K.: "Second Life: an overview of the potential of 3-D virtual worlds in medical and health education"; Health Information and Libraries Journal, 24, 4 (2007), 233–245.

[Campbell et al. 2002] Campbell, J.O., Bourne, R.J., Mosterman, P.J., Brodersen, J.A.: "The Effectiveness of Learning Simulators in Electronic Laboratories"; Journal of Engineering Education, 91, 1 (2002), 81–87.

[Chapman and Martin 1995] Chapman, G.M., Martin, J.F.: "Computerized business games in engineering education"; Computers & Education, 25, 1-2 (1995), 67–73.

[Clarke and Dede 2005] Clarke, J., Dede, C.: "Making Learning Meaningful: An Exploratory Study of Using Multi-User Virtual Environments (MUVES) in Middle School Science";

[Conklin 2007] Conklin, M.S.: "101 Uses for Second Life in the College Classroom";

[Dede et al. 2005] Dede, C., Clarke, J., Ketelhut, D.J., Nelson, B., Bowman, C.: "Students' Motivation and Learning of Science in a Multi-User Virtual Environment";

[Del Blanco et al. 2010] Del Blanco, Á., Torrente, J., Fernández-Manjón, B.: "Integrating Educational Video Games in LAMS: The <e-Adventure> Experience"; 5th International LAMS & Learning Design Conference "Sharing Great Ideas."Sydney, Australia, 83–91

[Del Blanco et al. 2012] Del Blanco, Á., Torrente, J., Marchiori, E.J., Martínez-Ortiz, I., Moreno-Ger, P., Fernández-Manjón, B.: "A framework for simplifying educator tasks related to the integration of games in the learning flow"; Education Technology & Society (In Press, expected publication year: 2012)

[Devendorf et al. 2009] Devendorf, M., Lewis, K., Simpson, T.W., Stone, R.B., Regli, W.C.: "Evaluating the Use of Digital Product Repositories to Enhance Product Dissection Activities in the Classroom"; J Comput Inf Sci Eng, 9, 4 (2009), 041008 (8 pages) .

[Dickey 2010] Dickey, M.D.: "World of Warcraft and the impact of game culture and play in an undergraduate game design course"; Computers & Education In press:

[Dougiamas and Taylor 2003] Dougiamas, M., Taylor, P.: "Moodle: Using Learning Communities to Create an Open Source Course Management System"; In: Kommers P, Richards G [eds]AACE, Honolulu, Hawaii, USA, 171–178

[Ebner and Holzinger 2007] Ebner, M., Holzinger, A.: "Successful implementation of user-centered game based learning in higher education: An example from civil engineering"; Computers & Education, 49, 3 (2007), 873–890.

[Edwards et al. 2001] Edwards, E., Elliott, J., Bruckman, A.: "AquaMOOSE 3D: Math Learning in a 3D Multi-user Virtual World";

[Farmer and Dolphin 2005] Farmer, J., Dolphin, I.: "Sakai: eLearning and More"; Manchester, UK, 22–27

[De Freitas 2006] De Freitas, S.: "Learning in Immersive Worlds: A review of game-based learning";

[de Freitas and Oliver 2006] de Freitas, S., Oliver, M.: "How can exploratory learning with games and simulations within the curriculum be most effectively evaluated?"; Computers & Education, 46, 3 (2006), 249–264.

[Gamage et al. 2011] Gamage, V., Tretiakov, A., Crump, B.: "Teacher perceptions of learning affordances of multi-user virtual environments"; Computers & Education, 57, 4 (2011), 2406–2413.

[Hays 2005] Hays, R.T.: "The effectiveness of instructional games: a literature review and discussion";

[Hiekata et al. 2008] Hiekata, K., Yamato, H., Rojanakamolsan, P.: "CAD Education Support System Based on Workflow"; , doi: 10.1007/978-1-84800-972-1_43.

[Hou 2012] Hou, H.-T.: "Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG)"; Computers & Education, 58, 4 (2012), 1225–1233.

[Hulme et al. 2009] Hulme, K., Kasprzak, E., English, K., Moore-Russo, D., Lewis, K.: "Experiential Learning in Vehicle Dynamics Education via Motion Simulation and Interactive Gaming"; International Journal of Computer Games Technology, 2009 (2009), 15.

[Ibáñez et al. 2011a] Ibáñez, M.B., Delgado Kloos, C., Leony, D., García Rueda, J.J., Maroto, D.: "Learning a Foreign Language in a Mixed- Reality Environment"; IEEE Internet Computing, 15, 6 (2011), 44–47.

[Ibáñez et al. 2011b] Ibáñez, M.B., García, J.J., Galán, S., Maroto, D., Morillo, D., Delgado Kloos, C.: "Design and Implementation of a 3D Multi-User Virtual World for Language Learning"; Educational Technology & Society, 14, 4 (2011), 2–10.

[Jenkins et al. 2003] Jenkins, H., Klopfer, E., Squire, K., Tan, P.: "Entering the Education Arcade"; 1:

[Johnson and Jonhson 1975] Johnson, D.W., Jonhson, R.T.: "Learning together: Group theory and group skills"; Pearson Education

[Johnson et al. 2012] Johnson, L., Adams, S., Cummins, M.: "NMC Horizon Report: 2012 Higher Education Edition"; Austin, Texas: The New Media Consortium

[Kemp et al. 2009] Kemp, J., Livingstone, D., Bloomfield, P.: "SLOODLE: Connecting VLE tools with Emergent Teaching Practice in Second Life"; British Journal of Educational Technology, 40, 3 (2009), 551–555.

[Ketelhut et al. 2006] Ketelhut, D.J., Dede, C., Clarke, J., Nelson, B.: "A multi-user virtual environment for building higher order inquiry skills in science";

[Khosrowjerdi et al. 2005] Khosrowjerdi, M., Kinzel, G.L., Rosen, D.W.: "Computers in Education: Activities, Contributions, and Future Trends"; J Comput Inf Sci Eng, 5, 3 (2005), 257–264.

[Lim et al. 2006] Lim, C.P., Nonis, D., Hedberg, J.: "Gaming in a 3D multiuser virtual environment: engaging students in Science lessons"; British Journal of Educational Technology, 37, 2 (2006), 211–231.

[Mayo 2007] Mayo, M.: "Games for science and engineering education"; Communications of the ACM, 50, 7 (2007), 30–35.

[Mayo 2009] Mayo, M.J.: "Video Games: A Route to Large-Scale STEM Education?"; Science, 323, 5910 (2009), 79–82.

[Mayrath et al. 2011] Mayrath, M.C., Traphagan, T., Heikes, E.J., Trivedi, a.: "Instructional design best practices for Second Life: a case study from a college-level English course"; Interactive Learning Environments, 19, 2 (2011), 125–142.

[Mikropoulos and Natsis 2011] Mikropoulos, T. a., Natsis, A.: "Educational virtual environments: A ten-year review of empirical research (1999–2009)"; Computers & Education, 56, 3 (2011), 769–780.

[Neufeld and Barrows 1974] Neufeld, V.R., Barrows, H.S.: "“The McMaster Philosophy”:An approach to medical education"; Journal of Medical Education, 49, 11 (1974), 1040–1050.

[deNoyelles and Kyeong-Ju Seo 2012] deNoyelles, A., Kyeong-Ju Seo, K.: "Inspiring equal contribution and opportunity in a 3d multi-user virtual environment: Bringing together men gamers and women non-gamers in Second Life®"; Computers & Education, 58, 1 (2012), 21–29.

[Prensky 2001a] Prensky, M.: "Digital Game Based Learning"; McGraw-Hill, New York

[Prensky 2001b] Prensky, M.: "Digital natives, digital immigrants."; On the Horizon. NCB University Press. 9:

[Ramani et al. 2003] Ramani, K., Agrawal, A., Babu, M., Hoffmann, C.: "CADDAC: Multi-Client Collaborative Shape Design System with Server-based Geometry Kernel"; J Comput Inf Sci Eng, 3, 2 (2003), 170–173.

[Rice 2007] Rice, J.W.: "New Media Resistance: Barriers to Implementation of Computer Video Games in the Classroom"; Journal of Educational Multimedia and Hypermedia, 16, 3 (2007), 249–261.

[Sancho et al. 2009a] Sancho, P., Fuentes-Fernández, R., Fernández-Manjón, B.: "Learning teamwork skills in university programming courses"; Computers in Education, 53 (2009), 517–531.

[Sancho et al. 2009b] Sancho, P., Fuentes-Fernández, R., Gómez-Martín, P.P., Fernández-Manjón, B.: "Applying multiplayer role based learning in engineering education: Three case studies to analyze the impact on students’ performance"; International Journal of Engineering Education 25:

[Sancho et al. 2009c] Sancho, P., Moreno-Ger, P., Fuentes-Fernández, R., Fernández-Manjón, B.: "Adaptive Role Playing Games: An Immersive Approach for Problem Based Learning"; Educational Technology & Society, 12, 4 (2009), 110–124.

[Squire 2003] Squire, K.: "Video Games in Education"; International Journal of Intelligent Simulations and Gaming, 2, 1 (2003), 49–62.

[Srinivasan et al. 2008] Srinivasan, V., Butler-Purry, K., Pedersen, S.: "Using video games to enhance learning in digital systems"; ACM, New York, NY, Toronto, Ontario, Canada, 196–199

[Sykes 2011] Sykes, J.M.: "Multi-User Virtual Environments: User-Driven Design and Implementation for Language Learning"; In: Vincenti G, Braman J [eds] Teaching through Multi-User Virtual Environments: Applying Dynamic Elements to the Modern Classroom. IGI Global, 283–305

[Tashner et al. 2005] Tashner, J.H., Bronack, S.C., Riedl, R.E.: "3D web-based worlds for instruction"; 2114–2118

[Warburton 2009] Warburton, S.: "Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching"; British Journal of Educational Technology, 40, 3 (2009), 414–426.