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SIMULATION EDUCATION IN THE INTERNET AGE: SOME EXPERIENCES ON THE USE OF PURE ONLINE AND BLENDED LEARNING MODELS

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ABSTRACT

In this paper we analyze several cases related to three different Spanish universities that make use of the World Wide Web to teach simulation courses online. These universities are the Open University of Catalonia, the University of Lleida and the Public University of Navarre. At these three universities different infrastructures, tools and learning models are employed to deliver simulation education online. All together, they represent a good example of how information technologies can be used in today's higher-education systems and, in particular, in the area of simulation education. In the paper, several course designs are covered and main difficulties associated with these online courses are highlighted and discussed. Intensive use of computer simulation software, collaborative e-learning practices and professional-oriented approaches are proposed as methodological policies to increase students' motivation for simulation topics.

1 INTRODUCTION

Simulation is an interdisciplinary knowledge area that combines computer science, mathematics, statistics and business management. Originally, it was mainly used to explore different management scenarios and system designs. Nowadays, with the outstanding improvements done in computer processing power, Simulation is able to provide pseudo-optimal solutions to ill-structured problems, thus being helpful in real-world decision-making processes. Hence, Simulation applications are found everywhere, from natural and social sciences to engineering, which explains why Simulation is taught at universities and colleges worldwide.

Information technologies (ITs) offer new ways to teach and learn Simulation and, in general, Operations Research. In particular, ITs innovations have driven the growth of distance learning opportunities, as students who are time bound –due to job or family responsibilities– or place bound –due to geographic location or physical disabilities– can now get access to Simulation courses at their convenience. Regarding the teaching and learning processes, there is an increasing tendency among universities to develop and use Virtual Learning Environments (VLE), which are sometimes combined with Management Information Systems (MIS) in order to implement Managed Learning Environments (MLE). In an MLE, all aspects of a course are handled through a consistent user interface, which is the standard throughout the institution. A growing number of physical universities, as well as newer pure-online ones, have begun to offer a selected set of academic degrees and programs via the Internet at a wide range of levels and covering a huge range of disciplines. While there are programs which require students to attend some campus classes or orientations, many programs are delivered completely online. In addition, several universities offer online student support services, such as online advising and registration, e-counseling, online textbook purchase, student governments and student newspapers.

Additionally, ITs facilitate the shifting from a traditional educational paradigm –centered on the figure of a masterful instructor– to an emergent educational paradigm which considers students as active and central actors in their learning process (Engelbrecht and Harding 2005). In this scenario, students learn, with the help of instructors, technology and other students, what they will potentially need in order to develop their future academic or professional activities. Accordingly, instructors provide students with course core materials and, additionally, with complementary learning resources such as web links, overhead presentations, software-based simulations, self-assessment tests, research articles, Java applets, etc. At the same time, they use to guide the learning process by setting up individual or collaborative learning activities –to which they may give assistance at different levels–, and by moderating and supporting discussions in either small groups or class forums.

This paper aims to present some experiences on the use of ITs in the learning and teaching of online Simulation courses. Thus, after discussing some of the benefits and challenges of e-learning, the paper describes three real experiences regarding the teaching of online Simulation courses. These experiences cover three different Spanish universities: the Open University of Catalonia (UOC), the Public University of Navarre (UPNA) and the University of Lleida (UdL). Hopefully, the comparison among these three cases will help other professors interested in e-learning experiences to develop their own online courses on Simulation.

2 EXPERIENCES AT THE OPEN UNIVERSITY OF CATALONIA (UOC)

The Open University of Catalonia is a complete online university which uses an asynchronous learning model, the student-centered educational paradigm impregnates all academic acts and activities. As a part of a wider academic catalogue, the UOC offers undergraduate OR and Simulation courses both to computer sciences and business management students.

2.1 MISIO: An Undergraduate Course in OR and Simulation

MISIO (Modeling and Simulation in Operations Research) is an undergraduate OR course that is offered to computer sciences students at the UOC. The main goal of MISIO is to introduce basic OR concepts and techniques to computer science students. The course syllabus is divided into three main blocks: linear programming (LP), discrete-event simulation (DES) and decision-support systems (DSS). These blocks are developed and evaluated in four online collaborative projects, which are distributed along the semester. The first project is related to the LP part, the second and the third ones are related to the DES part, and the fourth project is related to the DSS part. The MISIO course begins with a general overview of the OR discipline and with an analysis of the basic linear programming concepts and techniques. This first part of the course allows students to introduce themselves into the OR world and its potential applications to the solving of decision-making processes in engineering and business management. In the corresponding project, students develop their first collaborative project, which usually consists of the modeling and solving of a set of linear programming problems. The second part of the course focuses in discrete-event simulation. Here, the course introduces the student into the three main paradigms of discrete-event simulation –event scheduling, activity scanning and process interaction. In this second part of the course, which spans over eight weeks, students develop two collaborative projects, one related to the process interaction approach and another related to the event scheduling approach. Finally, in the third part of the course, students develop their final project. The main objective of this final project is to combine optimization and simulation techniques to create a complete DSS. Usually, this project requires the combined use of both LP and Simulation techniques in order to develop a DSS able to provide good solutions for a proposed routing or scheduling problem.

2.2 MS Thesis in Simulation

Once students finish their studies, they can select among several areas related to simulation to develop their MS thesis. One of these areas is linked with the development of models related to networks and distributed computer systems in the so called Castelldefels Project (Juan et al. 2007). This project consists of the development of a simulation model that accurately represents the real computer system that gives support to the e-learning environment at the UOC. This model must be developed with the help of network simulation software such as OMNET++ (www.omentpp.org) and/or OPNET Modeler (www.opnet.com). The main target of the Castelldefels project is to provide the computer system's managers with a realistic simulation model of their system. This model will allow the managers: (i) to analyze the behavior of the current system in order to discover possible performance problems such as bottlenecks, weak points in the structure, among others, and (ii) to perform what-if analysis regarding future changes in the system, including the addition of new Internet-based services, variations in the number and types of users, changes in hardware or software components, etc. By involving themselves in this project, computer science students not only learn simulation but also learn how it can be useful in the computer network arena. Another exciting area is related with the development of new simulation-based algorithms for the Capacitated Vehicle Routing Problem (CVRP) (Faulin et al. 2008). These algorithms can be used as an efficient alternative to other approaches based on metaheuristics (e.g. Simulated Annealing, Tabu Search, Genetic Algorithms, etc.), which usually are more difficult to be used in practice since they require complex fine-tuning processes. Here, the students' goal are to collaborate with their instructors in the designing, implementation and testing of new algorithms and their applications to routing or scheduling problems. Other areas are related with the use of simulation to improve queuing models –such as contact centers– (Faulin and Juan 2005), to estimate reliability and availability functions in time-dependent complex systems, networks and structures (Juan et al. 2008), or to perform environmental simulations –such as wildfire simulations– (Fonseca i Casas et al. 2004). The assessment methodology uses the principle of continuous evaluation based on scheduled homework. At each milestone, students must send their deliverables to the instructor, who reviews them according to the initial goals and provides the corresponding feedback to each student.

2.3 Technological Platform

When we talk about online learning we must distinguish between two main different groups of technological platforms: the subject-related software that students might use when completing their academic activity –e.g. Mathematica, Arena, Java, etc.–, and the online platform that facilitates communication among students and among students and instructors. Regarding the last one, UOC uses a proprietary e-learning platform which has been developed and improved through the last decade to fulfill their own online students' and instructors' requirements (Figure 1). The UOC basically uses an asynchronous learning model, which follows the abovementioned student-centered educational paradigm: at the beginning of the semester students access the course online classroom and, following the recommendations provided by their instructors, they download a complete syllabus of the course together with all associated learning materials and resources. Throughout the course, students are encouraged to participate actively in discussion forums, to develop collaborative learning projects and, specially, to follow a scheduled continuous assessment process, which typically consist of four or five homework activities. The UOC online platform supports forums, e-mail, notice boards, calendars, evaluation reviews, etc., thus allowing for a complete communication framework.

Figure 1: Screenshot of the UOC online platform

In order to complete each homework, students are free to use any of the software programs recommended by the instructor: to solve the first work, which is related with linear programming, they can use LINDO/LINGO (http://www.lindo.com), the GPL licensed software LPSolve (http://sourceforge.net/projects/lpsolve) or even Microsoft Excel. Students are encouraged to try different software tools and they are free to choose their favorite software in order to develop their first project, which usually involves the first four weeks of the course. For their second project, which involves the development of a simulation model following the process-interaction paradigm we usually make use of the GPSS language (Born and Ståhl 2004). To complete their third project, which is related with the event-scheduling simulation approach, students are encouraged to use the Java programming language. Here, students are invited to propose a realistic problem and try to solve it with the help of the instructor, which actively guides the solving process. Usually the proposed problems require some simplifications in order to be solved in a four-week period, but students are encouraged to develop a deeper analysis on the same problem during their MS thesis. Working on realistic projects is very interesting for students and it significantly contributes to increase their interest and motivation for operations research in general and simulation in particular. To build their simulation model, some different alternatives are possible: GPSS , JESIM Java classes (a very simple set of classes that allow the rapid development of an event-scheduling simulation engine) or LeanSim (http://www.leansim.com), which is a simulation environment developed at the Technical University of Catalonia (Figure 2). LeanSim incorporates the last technologies used in this area, like the possibility of modeling virtual-reality representations, distributed simulations, etc. The main interest of adding a new tool in this last project is to show an example of a state-of-the-art simulation tool. Depending on the particularities of the problem to be solved, some tools can be more efficient than others. Students have to discuss and argue their choice regarding the software they will use to develop their final project. It is interesting to notice that students understand and learn that the tool selection process is a key phase in the development of any simulation project (Rincon et al. 2005).

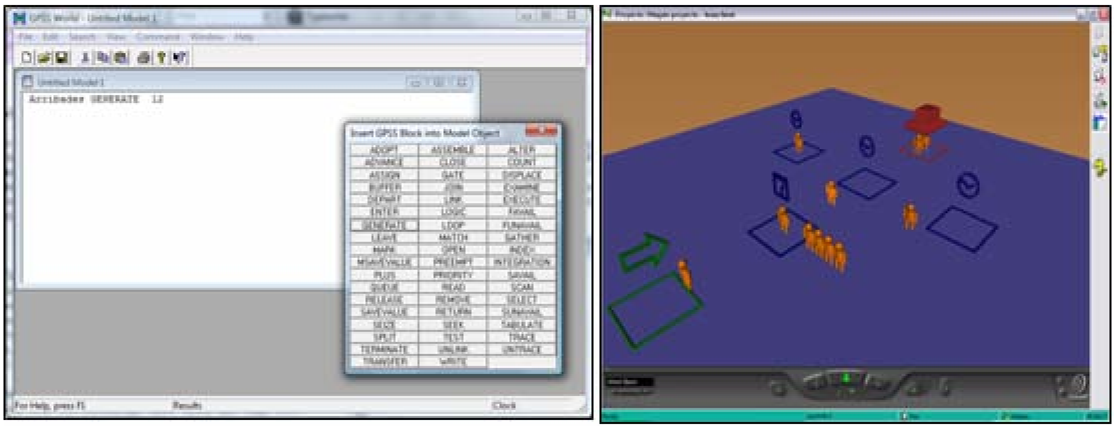

Figure 2: GPSSWorld and LeanSim® simulation environments

3 EXPERIENCES AT THE PUBLIC UNIVERSITY OF NAVARRE (UPNA)

The Public University of Navarre in Pamplona, Spain, belongs to a virtual network of nine Spanish universities which share teaching resources to offer a wider supply of subjects for their students. That group of nine universities is called the G9 group (www.uni-g9.net). In that context, an interdisciplinary group of professors designed a completed online subject entitled *Toma de Decisiones en la E-Empresa (Decision Making in E-Business)* for the whole G9 virtual campus. This subject has been built into the WebCT platform with the use of most of the teaching tools designed to be developed by the online instructor. Furthermore, this decision making subject is mainly devoted to help students understand the most important tools to decision making in virtual and service companies. Service companies are omnipresent in our current society along with virtual communities. This subject delves into the inner structure of these companies to help the students to grasp the best way to make decisions in that arena.

The key concepts which are taught in this subject are related to the use of linear programming, queuing theory and simulation to design a decision making course in virtual and service companies (Fitzsimmons and Fitzsimmons 2007). A panoramic view of this course can be seen in Figure 3. Concerning the inner structure of this course, students have to develop up to seven exercises, with the help of specific documents and books related to real decision cases, using linear programming and queuing theory. Usually, students have to make use of computer programs such as LINDO, LINGO, WinQSB or Microsoft Excel. Some of them can be downloaded in a free way over the Internet and others have an appropriate spread among the users so that they can be directly employed in the resolution of the exercises here provided. Finally, the assessment of this subject is carried out by the detailed solving of one of the two cases given to the students to test their abilities making decisions in an uncertain situation involving a myriad of problems related to virtual companies. *Decision Making in E-Business* is one-semester subject with four academic courses of real discussions of cases and difficult situations.

Concerning the challenges of online teaching of OR and Simulation courses, it is possible to say the following: (i) usually, there are no problems with the mathematical level of the subject because we do not take anything for granted, but we pay special attention to the self-learning of the students; (ii) the students motivation is normally high in this subject with a 60% of students following all the subject details; (iii) knowing the specific complexity of OR and Simulation subjects, we usually design tests and quizzes on line with affordable difficulty in relation to the traditional teaching in a face-to-face learning ; and (iv) we try to answer the students' questions in a maximum time of 12 hours in order to help the students to solve theirs doubts in a quick way and they have a useful feedback to perform their assignments.

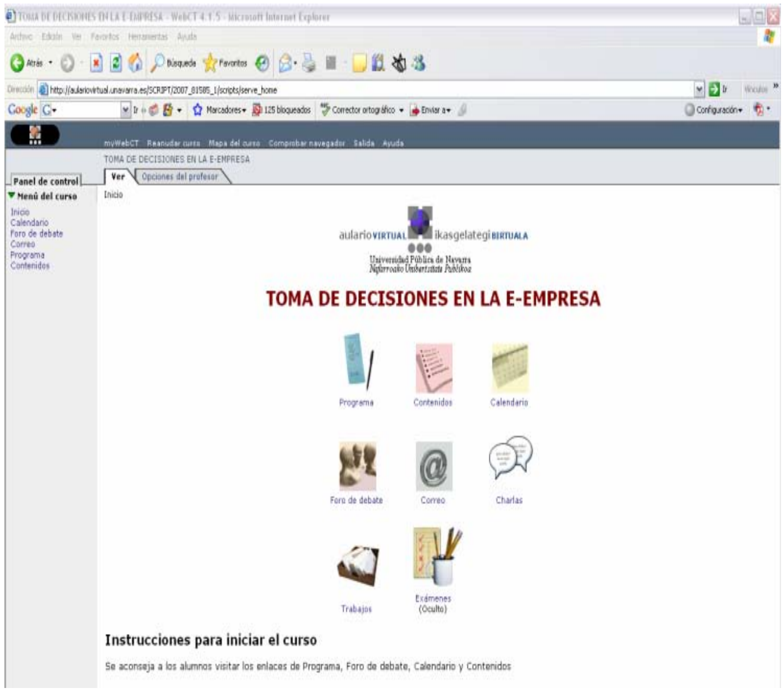

Figure 3a

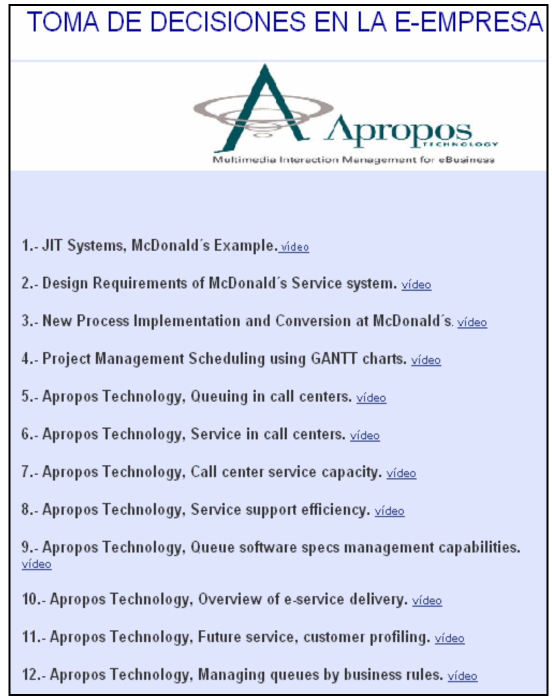

Figure 3b

Figure 3: WebCT course to teach decision-making (Figure 3a) along with a selection of real cases to analyze (Figure 3b)

3.1 Technological Platform

The Public University of Navarre uses the WebCT (www.webct.com) platform to teach online inside the G9 group of Spanish universities. This tool is also being used at the UNED University (www.uned.es - Spanish Open University which is specialized in distance and online teaching) to teach Simulation and other Operations Research subjects (Faulin et al., 2009). The main virtues of WebCT are connected to the specific use of thematic forums and the assignments tools. There are also other tools in WebCT for teaching and sharing information online, but considering the specific assessment tasks, the aforementioned ones are the most interesting to teach *Decision Making in E-Business*. Thus, WebCT allows a continuous feedback between students and teachers in forums and assessment tools. Our students have to solve one real case on line along with up to seven training exercises and for them their interaction in discussion devices are essential. In order to do so, the WebCT assignments tools are particularly motivating because it allows a quick interaction between students and teachers.

Therefore, we can say the performance of the Simulation subjects taught using WebCT in the UPNA and in the UNED would be really different without the possibilities provided by WebCT in assessment procedures. Nevertheless, we realize we could improve the feedback results given by the students in our subjects providing wiki or blogs platforms to enhance the cooperation activities in solving real cases and exercises. We consider these new tools are a challenge to be taken into account in the following versions of our subjects.

4 EXPERIENCES AT THE UNIVERSITY OF LLEIDA (UDL)

Optimization by Simulation (ObS) is a course on pseudo-optimization by using discrete-event simulation offered to MSc students in Business and Administration Science. This master program is taught in the Law and Economics Faculty at UdL. Most of the students come from the same Faculty after their graduation on Business studies. The course is offered online with optional face-to-face sessions developed in a computer classroom. All the academic resources –presentations, notes, exercises, solved exercises, articles, timing and scheduling– are available online. It is important to remark that regular students in the master programs have a weak mathematical background because they have only followed one introductory mathematics course. However, it is expected that students jump the gap between theory and practice, being able to solve real decision problems in their professional career. To overcome this paradox, the ObS course is based on learning by experimenting. Furthermore, it is intended to show students the limits of classical optimization applications and the practical alternative that simulation represents to get good enough solutions for many daily problems. The first edition started up in 2005.

The syllabus of the course is focused on optimization but under a somewhat original point of view. The perspective adopted is that the real world is complex and should be modeled to cope with optimization problems. As the model is a simplification of a real system, the solution of a classical optimization model is also imperfect. Optimal results are as good as the hypotheses in which the model is based. However, the ability of solving real problems depends on mathematical background. First approaches rely on deterministic models that are too simple for real instances. In this context, simulation is presented as an alternative methodology to deal with realistic decision problems. In many cases, simulation-based techniques are more intuitive and easier to implement than the corresponding analytical one for this kind of students. In both cases the goodness of the solution is tightly related to the accuracy of the model representing the real instance. Then, the emphasis along the course is put on the development of modeling skills in a similar way to that proposed by Cochran (2000), which is the main concern of the course.

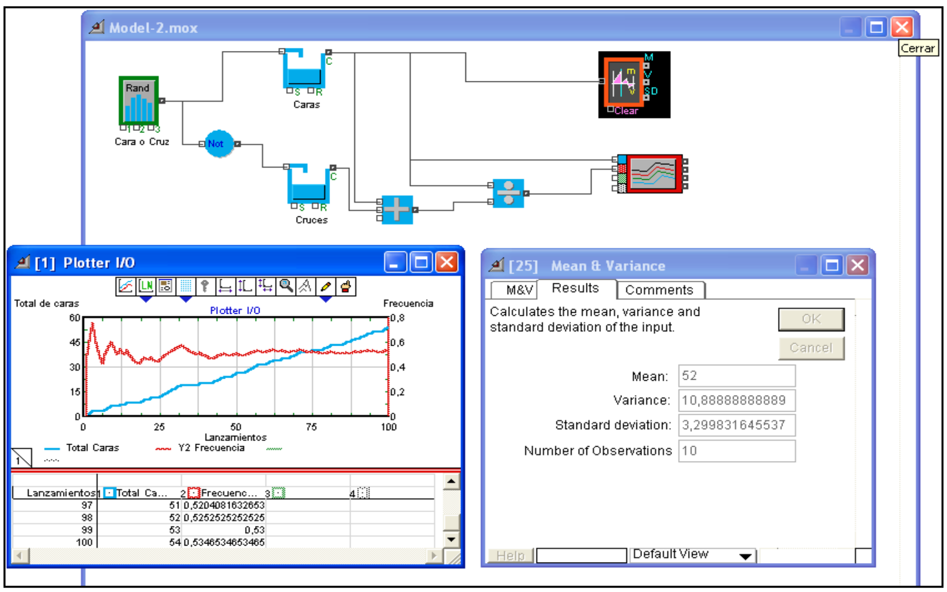

Figure 4: Using Extend to model an introductory simulation example

The program of the course is divided into three main parts: (i) Optimization methodologies, (ii) Discrete-event simulation, and (iii) simulation examples and discussion. The first part refreshes classical methodologies of mathematical programming and remarks their limitations in solving real instances. Linear programming is the main method recalled. Problems of several tens of variables and constraints are the more advanced models considered. At this point, the MS Excel solver is introduced, but some students find it difficult to use it to model large problems in an intuitive way sharing the criticisms that Gass et al. (2000) made about the use of spreadsheets to solve LP-problems. This fact affects directly the capacity of formulating a correct model with adequate constraints and corresponding objective function. Nevertheless it is shown how this simple methodology is less useful to non-linear non-deterministic real problems. Later, in the second part of the course, some problems that were already solved in the first part are used to show how simulation can perform good approximations to the optimal solution. Real problems where the exact solution is difficult to find are introduced here also. Hence, numerical approximations by using simulation models of the real system are proposed and the student learns how to develop a complete simulation project as described in Law and Kelton (2005).

The software programs employed to deploy the examples and analyze the different cases proposed are: (i) spreadsheets, and (ii) multipurpose simulation software: demo version of Extend (http://www.imaginethatinc.com). Extend is a powerful simulation tool allowing visual programming. There are not sessions devoted to learning specifically Extend. It is introduced gradually in the classroom by solving simple examples at the beginning. Main elements in extend models are blocks stored in pre-programmed libraries. The icon blocks exploit visual and intuitive skills of the students. Moreover, the modeling of the system is easy and flexible; the students can modify the model in just a few steps by introducing new blocks, deleting older ones, changing the parameters, etc. (Krahl 2003). According to our experiences in these courses, Extend facilitates the development of student's skills and also the modeling of complex systems. Furthermore, modeling with Extend facilitates the structure and visual presentation of the problem, as well as their modular development of constructed form, going from the general to the particular (top-down approach development). This methodology facilitates the achievement of good habits in modeling since they are related to the object-oriented programming paradigm. The third part is a discussion of instances solved by applying simulation and the analysis of results presented throughout the course (Figure 4). In this part, the use of simulation and, especially, the analysis of its results serves to review statistical concepts that students must have acquired: probability, distributions, descriptive statistics, estimators, hypotheses tests, etc. Every session begins with the proposal of different cases to the students for their discussion and solution. Emphasis is put on the steps of a simulation study and how OR can be useful to support the decision making processes. At the end of the course, it is expected that students can develop their own models, simulating and doing a good analysis of the problem results.

All in all, it can be said that this course has been planned attending to the following two principles: use of examples of increasing complexity and discussion of the employed methodologies, techniques and outcomes. Likewise, this outlook allows a stepwise progression in both teaching and learning of the simulation tool Extend. All this process is dressed with material available through Sakai: notes, exercises, tests, scientific papers, slides from presentations, Internet links to software or related material, the syllabus, grading and other useful information for the development of the course. Furthermore, regular activities are proposed to students in order to control their progress and instantaneous messaging keep instructor and students in touch for important events. These activities are qualified and students' marks are available online. This methodology has been proven to be very stimulating and successful for students following this subject.

Regarding the challenges of learning simulation online, it has to be noticed that the solving of realistic cases by means of specialized software helps students to be highly motivated and contributes to overcome possible deficiencies in their mathematical background. The use of a software with a friendly visual interface also contributes to stimulate students, since it facilitates the rapid development of simulation models. Finally, collaborative works and problems discussion increase the interaction among students and between students and instructors.

4.1 Technological Platform

The University of Lleida (UdL) has recognized the value of e-learning technologies in the context of a traditional teaching university. The UdL has many degrees that are offered by traditional teaching in a classroom. In this context, e-learning is seen not only as a complement of traditional teaching methodologies but also as a new stream to develop innovative courses. For this purpose, the UdL joined the Sakai project (http://sakaiproject.org/) on August 2005. Sakai is an online Collaboration and Learning Environment (CLE). The main trait of Sakai is that it is a free and open source product that is built and maintained by the Sakai community. Sakai is a Java-based, service-oriented application suite designed to be scalable, reliable, interoperable and extensible. As result, selected courses at UdL are offered online based on Sakai's e-learning technology. Under UdL's point of view, one important advantage of online courses for all those students working outside is the possibility of being enrolled in higher education programs.

5 CHALLENGES RELATED TO TEACHING SIMULATION ONLINE

Some of the instructors that are involved in the MISIO online course at the UOC are also face-to-face instructors at the Technical University of Catalonia (UPC). This dual role allows us to compare both learning models and better understand which are the real challenges of teaching simulation online. The course at the UPC is focused in understanding discrete simulation, continuous simulation, some formalization languages related to simulation, experimental design and the processes of verification and validation of simulation models. This course has several face-to-face sessions per week, which allow students to understand the main problems related to the practical applications of simulation techniques. In this practical sessions, both GPSS and JGSS simulation programs are used to introduce students in the modeling process through the process interaction paradigm. JESIM is used to teach Event Scheduling paradigm, and Arena, Witness, Simprocess, LeanSim and VenSim are used to illustrate examples of complete simulation tools. In the practical sessions, students follow a well defined outline to build a simulation model and finally develop a complete simulation project. Since students can solve the problems during the on-site sessions, supplying an online environment to facilitate further communication between students and instructors could be considered as optional. However, more and more students use their e-mail to ask questions during the problem solving of their homework. In fact, about 20% of registered students do not attend the face-to-face sessions, but they prefer to check the online information associated with the course from their home or their job locations. For that reason, even in this face-to-face environment it becomes necessary to implement an online platform to support the learning process. In the case of the UPC Computing School, a Virtual Campus named "El Racó" offers these communication functionalities (Figure 5). It is quite interesting to remark that, although having a different profile, both students from the UOC and the UPC seem to share their interest for learning with the help of information technologies and, in particular, by means of online platforms and resources. Likewise, both kinds of students see instructors as knowledge facilitators that can help them during the problem solving process. Therefore, both traditional face-to-face models and pure-online models tend to converge in blended models. Probably the main difference we have detected between UPC and UOC students is that the later ones usually need more motivation, mainly because of the lack of face-to-face sessions with instructors. Thus, it becomes important that the tools provided by the online platform or virtual campus facilitate this communication as much as possible. Of course, not only a good online infrastructure is needed, it is necessary an assertive behavior of instructors, seeking for students' motivation, and scheduling a continuous evaluation. In other words, instructors must actively use the online forums, e-mail and other educational tools to guide students and give them quick answers to their problems. Far from what it might seem at a first glance, being an online instructor usually implies more workload than being a face-to-face instructor, since every course detail must be perfectly planned beforehand: syllabus, learning materials, online labs, homework, continuous and summative assessments, students feedback, etc.

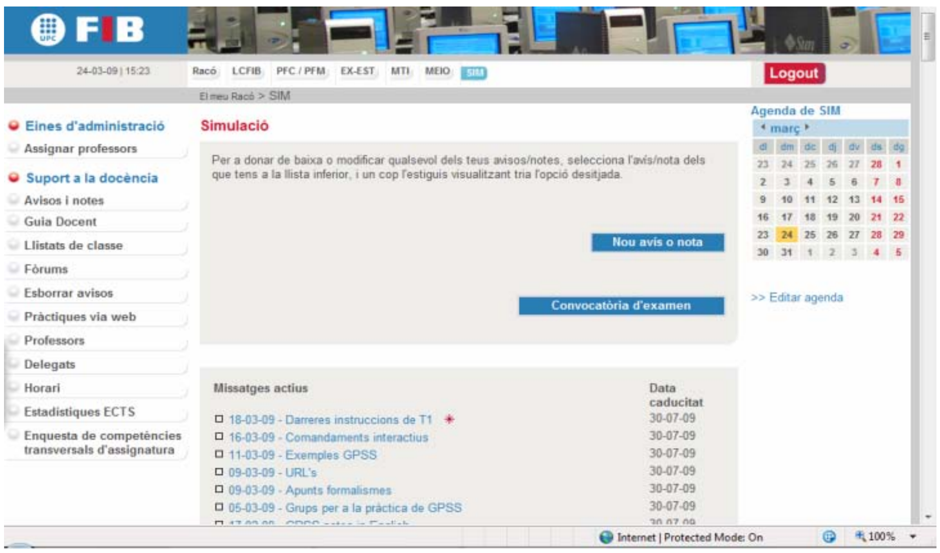

Figure 5: Online platform "El Racó" at the UPC Computer Science School

6 SUMMARY OF TECHNOLOGICAL INFRASTRUCTURE

Table 1 summarizes the topics, evaluation methodology and computer software used in each of the already covered simulation-related courses.

As has been previously stated, nowadays it becomes necessary to support any simulation course with an online platform so that communication among students and between students and instructors will be facilitated in all possible ways. Technological solutions vary from proprietary applications such as the one developed at the UOC or the one employed by the UPNA to open-source applications such as the one selected at the UdL. Table 2 summarizes some relevant data regarding each of the platforms considered in this paper.

Table 1: A comparative analysis of covered simulation courses

University and course name	Topics (program)	Evaluation methodology	Simulation and OR software employed
UOC - MISIO	Queuing theory, Discrete Simulation and Decision Support systems.	Four practical exercises (mini-projects) related to: queuing theory, simulation using the process-interaction paradigm, simulation following the event-scheduling paradigm, and a summative OR project.	- LPSolveIDE. - GPSS - JGPSS - JEventScheduling - LeanSim
UOC - MS thesis on simulation	MS thesis work related to simulation area.	Four summative mini-projects.	- OPNET - OMNET++ - Java or C/C++
UdL – Optimizations by simulation	Linear Programming and Discrete Event Simulation	Five practical exercises are requested periodically, discussion of papers, literature review and a final exercise solved with Extend.	- MS Excel - Extend
UPNA - Decision Making in E-Business	Queuing theory. Introduction to discrete simulation using Excel	Discussion of one final practical case, after having solved up to six voluntary exercises.	- MS Excel with simulation add-ins - WinQSB

Table 2: Comparative analysis of the analyzed virtual campus infrastructures

	Scenarios		
University:	UOC	UPNA (G9)	UdL
Online platform:	UOC Virtual Campus	WebCT	Sakai
License:	Proprietary	Commercial	Open Source (GPL)
Since:	1995	1997	2005
Users:	37,000+	25,000+	5,000+
Model:	Pure online	Pure online	Blended (hybrid)
Integrated tools:	Notice boards Email, Marks management Calendar	Notice boards Email, Calendar Discussion forums	Notice boards Email, Calendar, Test-maker, Marks management

7 CONCLUSIONS

We have described the simulation courses developed in three different Spanish universities, its assessment methodologies, and the technological infrastructures needed to perform this online teaching approach. Two of the universities covered in this paper (UOC and UPNA) use a pure online approach, while the other (UdL) uses a blended model that combines a traditional face-to-face methodology with online learning. Also, a comparative table for the different courses has been presented. As it has been discussed throughout the paper, students motivation is the key factor in online simulation education. To that end, use of simulation software, professional-oriented approaches and friendly online environments are necessary to complete successful simulation courses. In our opinion, some details given in the present paper could help the interested readers to develop their own online simulation courses.

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