Project-based course in experimental physics. Simulation of a real-life R&D program

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Keywords: University, Collaborative, Blended-learning, Project, Real-life

Abstract

Since 2004 the Applied Optics course of the Faculdade de Ciências e Tecnologia of the Universidade Nova de Lisboa (FCT/UNL) has a blended-learning format. In the academic year 2007/2008 we implemented a constructivist teaching-learning instructional design, based on collaborative activities simulating real-life R&D projects. At the end of the course we surveyed students' opinion through an anonymous questionnaire and we interviewed the professors. On the whole their reactions were very positive, even though both students and professors pointed out some critical aspects. In this paper we describe the course and we analyse the results of the surveys.

1 Introduction

The concept of "simulation" in Experimental Physics higher education is normally associated to the idea of virtual laboratory – where students test the behaviour and evolution of real systems – rather than to the idea of a constructivist environment, where the students look for solutions to different problems in the scope of a real-life organization[1]. Nevertheless, in the academic year 2007/2008, in the Applied Optics course of the FCT/UNL, besides introducing "virtual laboratory like" simulations we implemented a teaching-learning process based on collaborative R&D (Research and Development) projects, supported by synchronous and asynchronous e-learning, in a blended-learning format. We were interested in innovating the teaching-learning process and verifying if the new strategy was viable both for students and professors.

2 Project-based learning in a blended-learning context

The Applied Optics course is compulsory for students of the second cycle of the degrees in Physics Engineering, Biomedical Engineering and Teaching of Physics and Chemistry. It is attended on average by 50 students and lasts 14 weeks. The class meets twice a week, with two different professors, in two-hour face-to-face classes and two-hour sessions of collaborative laboratory activities. Since 2004 it has been supported by the Learning Management System (LMS) "Blackboard" as main asynchronous platform, associated to "Horizon Wimba" for synchronous activities.

Learners are invited to read the interactive Learning Units (LUs) before classes. These LUs contain a summary, short explanatory texts, graphs and animations with written or audio commentaries. Within each LU there are links to other LUs and to other kinds of resources (documents and web sites).

Before carrying out the experiments in the laboratory, students have to explore the preparatory Experimental Learning Units (ELUs), where they find the objectives of the experimental works and the links to documents and resources that help them to construct their own experimental protocol. These documents are the aforementioned LUs and technical documentation with instructions and information about equipment and devices. Each ELUs has an automated scoring test and students must score at least 80% before entering in the lab. In the laboratory they work in group: they carry out the experiment and then write a lab report.

[1] Ranieri (2005, p. 108-109), following Trinchero (2003), classifies simulations in virtual laboratories, constructivist laboratories and laboratories for the study of conceptual systems and modelling algorithms.

Furthermore, each student attends two online problem-solving synchronous sessions, normally in the last weeks of the course. These sessions were designed to have about 20 participants, to allow easier management by the professor. Participants communicate through written and oral chats, and share previously prepared documents. The four problems to be discussed in each session are available in the platform eight days in advance and students are invited to solve them on digital documents for later use online. The professor prepares the solutions of problems in MathCad and using the drawing facilities of the platform. At the beginning of each session one student is invited to present orally his/her solution and to show it on the screen; afterwards other students are asked to comment or present other solutions. The professor can show his own solution and ask someone to manipulate the drawings and the mathematical formulations from his/her own computer. We observed that in these cases communication, although not anonymous, is less formal than in face-to-face exercises classes and participation is wider. Since the professor can check students' work remotely, they do not have the feeling to be observed. This may help to establish a communication network in which the professor is not perceived as "controller" but as "moderator".

In the academic year 2007/2008 the course was reorganized around collaborative projects simulating real-life R&D activities. As a consequence, traditional lab experiments were reduced from seven to four, and theoretical classes were partially re-organized in function of the projects. This new pedagogical approach was introduced keeping in mind the constructivist instructional design proposed by different authors (Jonassen, 1999; Hannafin, 1999; Mayer, 1999), the five principles of learning theorized by M.D. Merril (2001, in Ranieri 2005) and the experiences of two universities engaged in the promotion of active learning (Politecnico of Milano[2] and University of Delaware[3]).

Taking as a reference the problem-based physics courses of the University of Delaware we proposed three R&D themes that would be engaging but relatively simple, embedded in a realistic scenario but feasible mastering the concepts presented in two or three LUs and using the facilities of the Applied Optics Laboratory. Students could start to work on the projects since the very beginning of the semester because, being at their fourth college year, they were already familiar with laboratory work. The projects to be delivered to hypothetical clients were:

- Apparatus and quality control process of track-to-track distance in a CD;
- Complete Optical designs of two magnifying glasses for office and for

[2] Sancassani and Casiraghi (2006)

[3] www.udel.edu/inst/ (retrieved on 28.11.07)
http://www.physics.udel.edu/wwwusers/watson/phys345/lab/flashlight.html (retrieved on 28.11.07)

precision works;
- Complete Optical designs of mirrors for aesthetics and for street corner vision.

Students were supposed to work as an engineering company and organised themselves in seven groups of seven; within the teams they spontaneously assumed different roles. Each company applied through the LMS for one project. They had to write a Proposal, based on a template provided by the "program manager" (i.e. the professor), where they would explain how to reach the objectives required. Rules of the call for tenders, templates for written documents, contents and resources (LUs, ELUs, bibliography and web sites) were available in the LMS. Once discussed with the "program manager" and approved, the project was executed and a final report was written and delivered to the "program manager". In the end there was a seminar, where all groups presented their works and defended the solutions implemented. Communications were held by the spokesperson of the group and by three other people of the team, randomly selected by the professor at the time of the seminar. A committee assisted to the discussion and assessed the works presented. To help students to organize all these materials, conceptual maps of the whole course and of each project (see an example in figure 1) were available in the LMS.

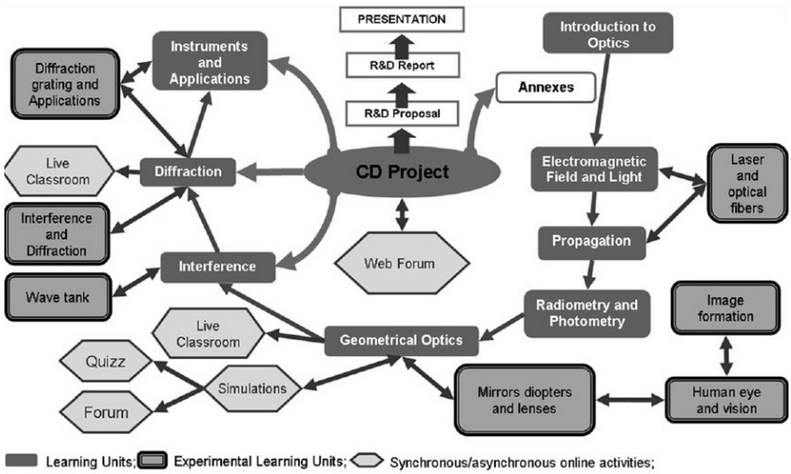

Fig. 1 – Example of a conceptual map

Furthermore, we opened a web forum that was meant to facilitate and promote communication among students and between teachers and learners. It was called "Forum for Doubts" and was devoted to clarify students' questions about the contents and the organization of the course.

Finally, for what concerns the contents, we enriched the course's materials with a virtual spherical dioptre. In this simulation the simplified representation of a spherical dioptre can be manipulated varying some parameters. As a result the drawing representing the properties of the system change, allowing the visualization of concepts that students tend to understand at a mathematical, but not physical, level. The simulation is associated to a multiple-choice questionnaire with automated scoring, which guides the exploration of the properties of the spherical dioptre. A deep understanding of this system is fundamental for the realization of the R&D projects.

Summarizing, during the Applied Optics course students have to develop a collaborative R&D project and four team laboratory assignments, they take part in two problem-solving synchronous sessions and in preparatory asynchronous activities. During face-to-face classes they discuss the theoretical issues presented in the LUs and problems arising from the projects. LUs and laboratory activities are the backbone of the course, but instead of marking a sequence of almost fixed steps, they shape a relatively flexible scaffold, aimed to help students to find their way for solving the real-life problems posed by the project. In this process students are called to take autonomous decisions and the decision process was not monitored by professors. The professor, in fact, played the role of an expert mentor and consultant who supports the student.

In the final assessment the collaborative R&D project accounts for 40% of the grade; laboratory activities for 30%; the final written exam for another 30%.

3 The course evaluated by the students

At the end of the course students were asked to answer an anonymous online questionnaire to evaluate the whole teaching-learning process. The enquiry included 21 multiple-choice questions and two open questions for comments on positive and negative features of the course. Overall 25 students out of 51 answered to all questions.

Most of them really appreciated the new format of the Applied Optics course, namely in what concerns the project: 72% said that they were satisfied or very satisfied with the course organization, 12% said they were not satisfied and 16% was neither satisfied, nor unsatisfied. The collaborative project was considered a very positive experience by 44% of students and positive by 52%, while 4% said that it was neither positive nor negative (figure 2). A student observed that «the project allowed to acquire new skills, many of which are not even [formally] taught».

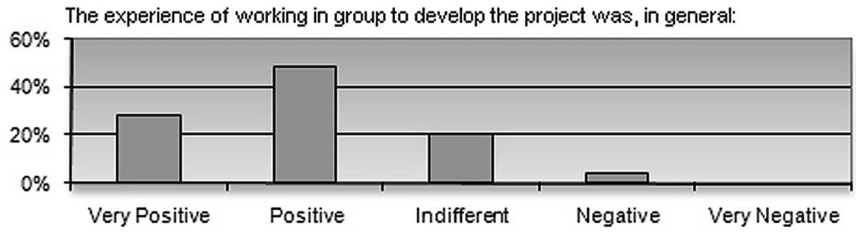

Fig. 2 – Students' answer to the question about working in a collaborative project.

All students said that they agreed with the statement that «Knowledge acquisition was enhanced through project development» and almost everybody found that it was motivating (16% very motivating, 52% motivating, 32% had no opinion). That notwithstanding, not all students said that they were willing to have more courses based on collaborative projects. This might depend on the fact that for some of them the collaborative project made the Applied Optics heavier than other courses, namely for what concerns time expenditure. This could be partially related to the fact that, not surprisingly, not all groups had good internal dynamics or an equal participation to the work. One of the students' most frequent comments was that groups were too big, and that the ideal dimension would be of three or four people. Someone noted, anyway, that having to work in big groups was positive, as it gave the chance or obligation to undertake a challenging task.

Although technical problems hampered the work on the spherical dioptre simulation and some problem-solving synchronous sessions, globally we had a positive feedback about the e-learning solution. For example, having been asked to comment the statement «Contents available match well my learning needs», 84% of students said that they agreed or completely agreed, and 16% said that neither agreed nor disagreed. These answers are consistent with those given by participants to previous editions of the course (Maneira *et al.*, 2007), and confirm that quality contents, resources and interfaces, produced in close collaboration between teachers, instructional designers and graphic designers, are key factors for successful e-learning (Maneira *et al.*, 2008).

The web forum had little activity during the course: only 15 students and one of the professors posted messages in the "Forum for doubts", for a total of 33 posts. We think it was due to the fact that professors were not prepared to plan, stimulate and moderate a forum and probably also to the fact that students spend on campus many hours a week, and therefore may not feel the need to communicate through a web forum. Nevertheless, 48% of the students said that the web forum was useful[4]. It is also interesting to record that, while in previous courses nobody showed up during the professors' office time, in this year, due to the challenges presented by the collaborative project, students looked very often for the professors out of classes.

4 The course evaluated by professors

In an open oral interview the two professors said to be very satisfied with the project-based teaching approach, because it promoted stronger participation and proactive attitudes among students. They observed that, in contrast with what happens in the traditional experimental laboratory activities, where students tend to mechanically execute a protocol, when engaged in a real-life project they are more creative. One professor observed: «They took the project very seriously and seemed actually involved in role playing, acting as real members of a company […] they were clearly enjoying it». Both of them noticed a healthy competition among the groups and thought that the quality of the final projects was generally good, with some groups presenting excellent works, denoting professional engagement and entrepreneurial attitude.

Compared to the previous academic year no difference was observed in the average final grade, but it does not mean that the implementation of a different pedagogical paradigm did not positively affect the learning process. In fact, in the final assessment we could not properly measure very important skills and behaviours, like proactive attitudes, creativity and the ability to cope with the challenges of real-life work in group.

As final remark professors pointed out that, although very positive under the pedagogical perspective, the project-base teaching approach was very demanding in terms of time.

Conclusion

Constructivist simulations based on collaborative projects can effectively improve the teaching-learning process in Science and Technology, generating interest and satisfaction both in students and professors. The didactic strategy based on collaborative projects is highly demanding in terms of time and interactions and so the use of a blended-learning format is fundamental. In fact, it is possible to use the LMS to build a scaffold that gathers contents, resources, conceptual maps, self- assessment units and communication tools. It helps students to organize their work and their knowledge, and consequently allows more dynamic participation in theoretical classes and in the laboratory.

[4] This might depend on the fact that many students are aware of the potential usefulness of forums, independently from this particular case. A prerequisites survey showed that 15% of them regularly participate in web forums, 53% do it seldom and 32% have never done it; 26% use web chats regularly, 47% seldom and 26% have never used it.

In order to be effective, online resources and activities have to be carefully designed and planned. To further develop this work and to extend it to other courses, professors need adequate training, and technical support must be improved, both in quality and quantity. For what concerns the R&D projects, it would be better to work in small groups, of no more than four persons.

In spite of some critical points, our experience shows that in Experimental Physics courses it is possible to enlarge the use of simulations from the simple virtual lab to a kind of "role playing", based on collaborative, real-life projects that foster a proactive attitude towards learning.

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