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Blended-learning in Science and Technology. A Collaborative Project-Based Course in Experimental Physics

Silvia Di Marco, Universidade de Lisboa (FCUL, Portugal)
António Maneira, Universidade Nova de Lisboa (FCT/UNL, Portugal)
Páulo Ribeiro, Universidade Nova de Lisboa (FCT/UNL, Portugal)
M.J.P. Maneira, Universidade Nova de Lisboa (FCT/UNL, Portugal)

Summary

This work describes a science and technology course in the Universidade Nova de Lisboa (Portugal), and its evolution towards a blended-learning format and a constructivist instructional design based on collaborative projects. The core of our work was to identify critical points and recommendations concerning the use of e-learning and project-based learning in an Applied Optics course where laboratory activities are a relevant part of the curriculum.

Asynchronous and synchronous e-learning tools and strategies were adopted in 2004 (interactive learning units, tests for self-assessment and online sessions for collaborative problem-solving), and later on, in 2007, we reorganized the course around collaborative real-life projects aiming for a constructivist teaching-learning model.

Overall, collaborative projects were positively rated by students, who appreciated experiencing a real-life “R&D” situation, and said that it enhances knowledge acquisition. Professors observed that this teaching method promotes stronger participation and a more proactive attitude. Furthermore, it was confirmed that well designed e-learning tools and activities are useful in supporting self-learning, a precondition for a creative approach to lab activities and projects. Synchronous online sessions for problem-solving were highly appreciated, because they allow software sharing and immersive remote communication. On the contrary, web-forums did not reach the expected results.

Our conclusion is that e-learning and experimental collaborative activities can be successfully combined to foster meaningful learning, although this is demanding in terms of effort and time. Collaborative projects and rich learning environments are two key features in constructivist instructional design and help students to develop a proactive attitude towards learning, as they have to deal with many kinds of resources instead of receiving a closed set of information, and this requires knowledge management skills. Furthermore, students need to put in place knowledge and skills to implement the project within a group. This implies the possibility to learn together with the others in a dynamic process, but also the need to explain, share and possibly defend particular ideas within the work-group.

Keywords: University course, Portugal, Collaborative learning, Blended learning, Synchronous e-learning, constructivist model, participation, e-learning tools

1 Introduction

This work describes the Applied Optics course of the Faculdade de Ciências e Tecnologia of the Universidade Nova de Lisboa (FCT-UNL), and its evolution towards a blended-learning format and a constructivist approach. It helps to identify key points and recommendations about the use of e-learning and project-based learning in experimental science and technology courses, where practical laboratory activities represent a relevant part of the curriculum.

The evolution of this course occurred in two phases: the first one, started in 2004, was characterized by the progressive introduction of e-learning for asynchronous and synchronous activities, i.e. interactive Learning Units, tests and quizzes for self-assessment, online sessions for collaborative problem-solving. In this phase the pedagogical approach was mainly objectivist, with a first effort to avoid behaviourism (Ally, 2004) in lab activities. In the second phase, implemented since the academic year 2007/2008, we made an effort to reinforce constructivist learning, restructuring the course around collaborative real-life projects and enriching the online environment through Java simulations and web forums.

The Applied Optics is a compulsory course for students of the of the second cycle (according to the European Union Bologna system) leading to the Master's degrees in Physics Engineering, Biomedical Engineering and Teaching of Physics and Chemistry. It is also an optional course for the students of the Master degree in Electrotechnical and Computers Engineering. The transition from the traditional face-to-face teaching-learning system to the web enhanced solution was introduced in order to reach different goals. For what concerns students these goals are:

- To foster individual study and self-assessment as prerequisites for a more constructivist approach to laboratory activities;
- To encourage them to become responsible for their own learning;
- To offer the opportunity to engage in online activities, synchronous and asynchronous, acquiring experience in the use of different software tools;
- To offer them the opportunity to work collaboratively online, experiencing situations similar to what they will probably meet in their future work;
- To facilitate meaningful learning through an improved graphical interface and interactive learning units.

From the institutional and teacher perspective the goals are also:

- To test the efficiency and performance of the available e-learning tools in view of further development of new online courses;
- To introduce progressively information and communication technologies (ICT) tools in traditional courses, avoiding quality gaps in the learning-teaching process of different academic years.

2 The applied optics course between 2004 and 2007

The Applied Optics course, attended on average by 50 students, lasts 14 weeks, i.e. 70 hours, plus individual study and lab reporting. The class meets twice a week, with two-hour sessions of in-class lecturing and two-hour sessions of collaborative laboratory activities or online synchronous problem-solving. Since the academic year 2004/2005 the whole course has been supported by the Learning Management System (LMS) Blackboard-Horizon Wimba that allows synchronous and asynchronous activities, and where students find a variety of learning resources. Learners are invited to read the interactive theoretical Learning Units (LUs) available in the LMS before classes. As prerequisite to the lab activities they have to explore the preparatory Experimental Learning Units (ELUs), which describe the objectives of the lab activities, as well as experimental equipment and the tools. Students have to pass an automated assessment test in order to be allowed to access the lab. More importantly, they can use the ELUs as a guide to set up the experimental protocols. Lab protocols, in fact, are not pre-constructed by the teachers, in order to discourage behaviourism. With the help of the LUs and ELUs students have to search for theoretical laws, as well as for different methods and procedures, and then link all the elements, “constructing” and taking responsibility for their own protocol[1].

Two problem-solving[2] sessions are generally run in the last weeks of the course. They are performed online using the Horizon Wimba “Live classroom”, which allows students and teachers to share screen and applications, i.e. text editors and mathematical tools like MathCad, and to communicate via written chat and audio. The instructor acts as a moderator. In addition, participants can share and operate on drawings through the e-board and the teacher can browse the Internet showing useful resources to the students. This learning architecture, progressively implemented between 2004 and 2007, represents the first phase of the Applied Optics course in the blended-learning format **(Figure 1)**.

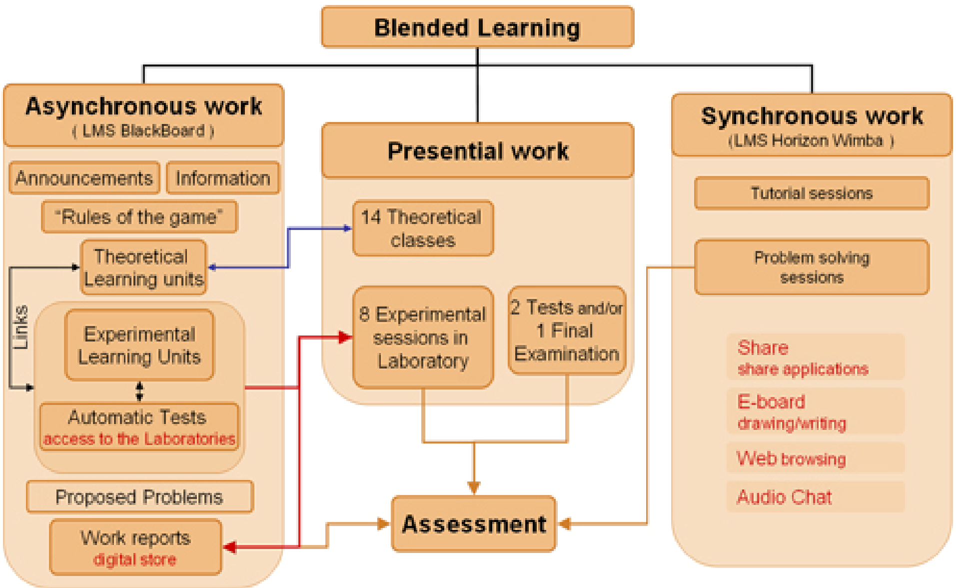


Figure 1. Representation of the blended-learning solution implemented between 2004 and 2007

3 Combining e-learning and constructivism

At the end of 2007 we introduced further innovations aiming to reinforce “constructivist collaborative learning”. In order to accomplish this goal we worked on four parallel lines: analysis of the 2006/2007 edition of the course, definition of a theoretical framework concerning mostly constructivism (Jonassen, 1999; Hannafin, 1999; Mayer, 1999; Watts & Pope, 1989; Von Glaserfeld, 1990), search for experiences of other universities engaged in the promotion of active learning in scientific field and analysis of e-learning features and models (Calvani, 2005; Ranieri, 2005; Di Marco, 2008).

The exploration of the literature showed us that constructivism is an umbrella term, which gathers different schools of thought, sometimes conflicting with each other. Supporters of “radical” constructivism assert that it offers an insight into human learning, but it says little about pedagogy and didactics, because a teacher cannot control learning (Towers, 2002). Others defend “trivial” constructivism, claiming that as any other epistemology it can be pragmatically used to design sophisticated learning environments (Jonassen, 1999; Hannafin, 1999) and contents (Mayer, 1999). According to this view constructivism has many overlapping features

[1] In this case the main constructivist element resides in putting into action the experimental method, formalized in the experimental protocol, entirely prepared by students before accessing the lab. The collaborative experimental activities in laboratory and the corresponding report are a consolidation and test of this process.
[2] Problems presented in these sessions are “traditional” physics problems, i.e. well-defined and well-structured, and they have a unique numerical and graphical solution.

with objectivism and both can be used as complementary theoretical frameworks for instructional design. In practice we chose to follow the operational definition of constructivism given by Calvani and Rotta, who say that a constructivist teaching-learning process should endorse: construction and not reproduction of knowledge; contextualization rather than abstraction (through authentic tasks and real-life cases); presentation of multiple and complex visions of reality aimed to stimulate reflection and metacognition; emphasis on cooperative building of knowledge (Calvani and Rotta, 1999 in Ranieri, 2005). The viability of this pedagogical approach was reinforced by the analysis of the problem-based learning approach of the University of Delaware[3], which puts together the cognitivist principles of learning of Merril (2001) with a strong emphasis on collaboration and real life problems, two key features of constructivism.

3.1 Collaborative project for problem-based learning

The introduction of a collaborative project to be developed along the semester was the most significant innovation for the 2007/2008 edition of the Applied Optics course. The projects were designed taking as reference the problem-based learning approach of the University of Delaware: they were engaging but relatively simple, embedded in a realistic scenario but feasible mastering the concepts presented in two or three Learning Units. They were introduced at the very beginning of the semester speculating that it would be motivating for students to know what kind of problems they would be able to solve by the end of the course (Merril, 2001). We assumed that this instructional strategy would be effective because the students enrolled in this course are already at their fourth college year, and they are familiar with lab activities; furthermore, as they had the whole semester to develop the project, they would have enough time to develop the knowledge and skills required to realize it[4].

In practice, three R&D (Research and Development) topics were proposed, and the rules of the simulated Research Program "contract bid" were presented in the LMS. The projects to be delivered to hypothetical industrial 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 precision works;
- Complete Optical designs of mirrors for aesthetics and for street corner vision.

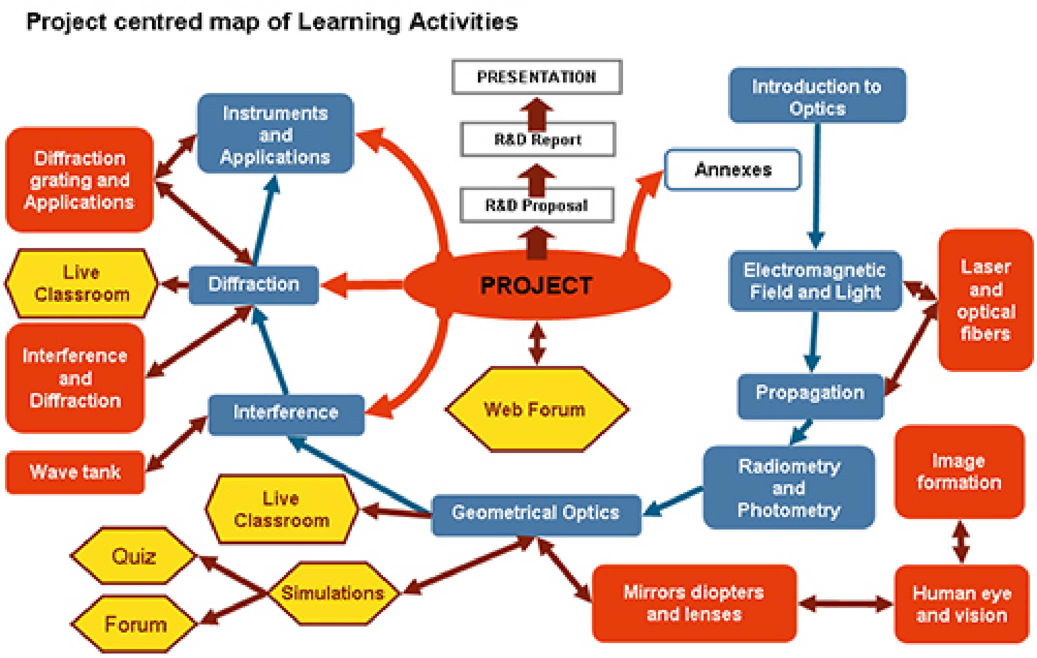
Students organised themselves in seven groups of seven, and each group proposed itself through the LMS to carry on one project, indicating the order of preference among the three options. Taking into account submission dates and preferences, each project was assigned to two or three groups. Each group wrote a Project Proposal to achieve the project objectives. The proposals had to obey to a template provided by the "Program Manager" (the professor). Once approved, the project was executed and a Final Project Report was delivered. As final activity there was a seminar, where all groups presented their works and defended the solutions implemented in a thirty minutes communication. Communications were delivered by one spokesperson elected by the group and three other elements of the team, randomly selected by the professor during the seminar, obliging all students to be present and prepared for the presentation. A committee assisted to the discussion, which was moderated by one of the professors.

To prepare the project proposal, practical work and final report, students had rules, templates, resources and conceptual maps available in the LMS. The conceptual maps **(Figure 2)** help to visualise the theoretical knowledge needed to achieve specific objectives, linking each project to specific LUs and to additional resources, as selected bibliography and web sites. The real life

[3] Our projects have been inspired by some problems available in the web site of the University of Delaware, www.udel.edu/inst/ (retrieved on 28.11.07); www.physics.udel.edu/~watson/scen103/colloq2000/main.html (retrieved on 28.11.07)

[4] Antonio Calvani (2000; in Ranieri, 2005) remarks that the use of problem-solving, in the forms suggested by the Gestalt concept of *insight* or by Bruner's discovery learning, requires a considerable expenditure of time, and it is viable only in specific contexts, with learners already familiar with the domain of knowledge.

project replaced three of the seven laboratory assignments present in the previous editions of the Applied Optics course.



Blue squares - Learning Units;
Red squares - Experimental Learning Units, i.e. experimental activities;
Yellow hexagons - Synchronous/asynchronous online activities;
White squares - activities related to the collaborative project

Figure 2. Representation of the blended-learning solution adopted in the academic year 2007/2008

Comparing the new structure of Applied Optics course (Figure 2) with the one reported in figure 1, we can see the passage from a rather linear pathway, fitting a quite objectivist paradigm, to a networked structure, more consistent with a constructivist model. The whole course process, from the initial project introduction to the final presentation, represents a good approximation to the five principles of learning theorized by Merril (2001): the problem is presented in a realistic context, offering students the proper instruments for activation and demonstration. At the same time they are required to apply the knowledge to a practical objective and in the end they have to publicly show and defend their work. Learning units and laboratory activities continue to be the backbone of the learning and teaching process, but instead of marking a sequence of almost fixed steps, they shape a relatively flexible scaffold, aimed to help students to find solutions for the collaborative project, acquiring the necessary concepts and skills. Anyway, it is important to emphasize that also in the previous versions of the course the program was adapted to students' needs, because teachers modulated the work pace accordingly with identified student's difficulties, dwelling longer on some topics and omitting others. This attitude was further developed by the endeavours of the projects, and the professor's role gradually shifted from that of a person who possesses the knowledge and transmits it, to that of an expert mentor and consultant, who supports learners in the process of knowledge construction.

3.2 Java simulation of a spherical diopter

Given its theoretical and experimental nature, the learning environment of the Applied Optics course has always been quite rich and can satisfy different ways of learning. Nevertheless the professor in charge of the course pointed out the need for more interactive LUs and simulations, in particular for what concerns a pivotal topic of geometrical optics, the spherical diopter. This system relates to image formation and is fundamental to the understanding of lenses. However, as it does not find many practical applications, students often understand it from the geometrical and mathematical perspective, but do not actually come to visualize the optical phenomena implied. That is why it was decided to introduce in the LMS an applet simulating a spherical diopter, which could be manipulated by students varying parameters in three different virtual experimental activities. This simulation, which was supposed to be the first step toward the creation of a Virtual Laboratory, was accompanied by a multiple-choice test with automated score evaluation, designed to stimulate an accurate manipulation of the parameters and the observation of the response of the virtual equipment displayed by the applet. Questions had the aim to assure that students would manipulate the simulation in all the possible ways; in some cases the answer comes from the observation of the images, in others it requires taking note of values and drawing graphs.

3.3 Web forums

In order to promote alternative ways of communication among learners and between learners and professors we decided to start to use web forums. We assumed that they would help to enhance interaction among students and teachers (Cristini & Nestani, 2003), and would contribuite to the creation of one-to-one communication, which is normally scarce in traditional courses[5] (Uggeri, 2003). Furthermore, one of our objective was to set up asynchronous online activities (e-tivities), that are supposed to offer students the possibility to explore information at their own pace and react to it before hearing the views and interpretations of others (Salmon, 2002). As the course has about 50 students and two teachers (one professor and one assistant professor), we thought that we could create two parallel forums with each professor moderating a group of 25. Two web forums were designed: one called "Forum for doubts", was devoted to students' questions regarding any issue related to the course. It was presented as a supporting service, substituting the traditional office time for one-to-one explanations, but also as a community space, where students were invited to help each other in a sort of peer tutoring. Of course, it is very common for students to study in pairs or groups, comparing notes, "repeating" lessons, solving problems and trying to answer doubts. Through the forum we wanted to encourage this practice and increase the number of beneficiaries of any question/answer exchange. Furthermore, as stated in the introduction, we thought that the use of a variety of online communication tools would be an asset by itself, because it helps students to become confident with a medium that they could use in future courses, namely post-graduation, and in future jobs. This forum was also supposed to be used to introduce students to a communication system that many of them still did not know, so they would be confident enough with it by the time the discussion forum would be introduced.

The second forum was devoted to an e-tivity connected to the simulation. It was introduced by a short text written in informal style, which invited students to take part into the e-tivity, paying attention to their colleagues' answer and to all the comments posted by professors. The invitation stressed the advantages of participating in the forum to learn from others' ideas and to gain "bonus" grades and the formative nature of this activity. The description of the e-tivity was introduced by an intriguing question and then instructions were detailed; some organizational tips were also reported, and the formative nature of the activity was stressed once again, inviting students to report to the instructor for any question concerning both the problem and the underlying physical and geometrical concepts.

3.4 Students' assessment and grading

At the beginning of the course students were informed that the assessment and grading would include the collaborative project (35%, with 10% for the R&D proposal, 10% for the report and 15% for the final presentation), the activities related to the simulation (10%), the participation in synchronous problem-solving (10%), the laboratory activities (practical work and final reports 20%) and the final exam (25%). However, due to technical problems and professors' difficulties in following e-tivities, and in order to promote fair grading, new percentages were attributed to the main items of the course: 40% to project; 30% lab activities; 30% to final written examination (Figure 3).

[5] Matteo Uggeri (2003) remarks that in traditional face-to-face classes only two or three students react to the standard teacher sentence "If you didn't understand something or want to deepen any topic, feel free to ask", while in distance learning the number of questions per student asked to the instructor, via forum or e-mail, is much higher.

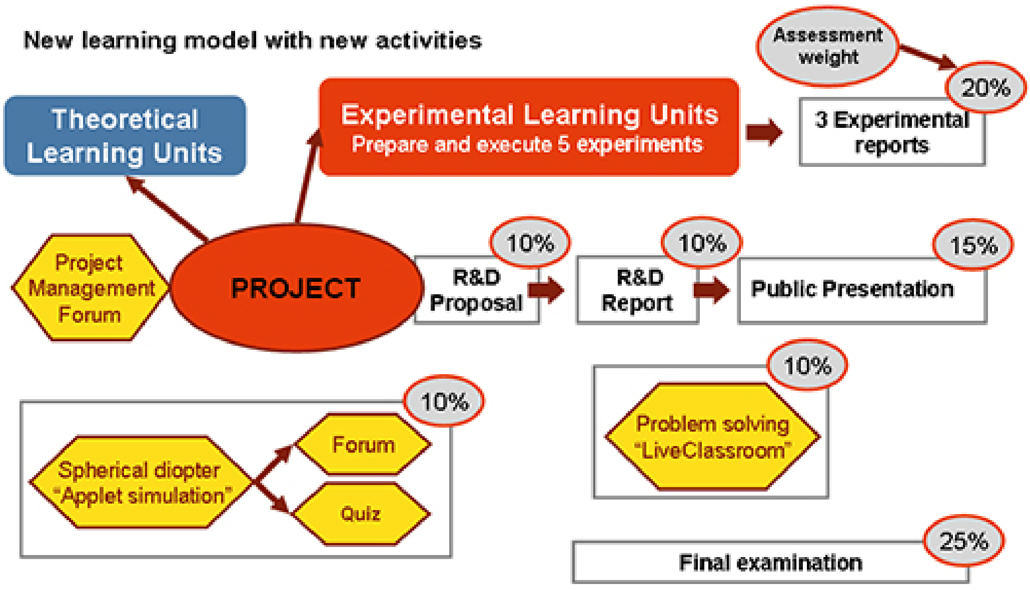


Figure 3. Representation of the students' assessment and grading scheme adopted in the academic year 2007/2008

4 Results: students reactions and opinions

At the end of the course students were asked to answer an anonymous online questionnaire aimed to evaluate the whole teaching-learning process. The enquiry included 21 multiple-choice questions, related to the general quality and organization of the course, to the collaborative project and to the online synchronous/asynchronous activities, and two open questions for comments on positive and negative features of the course. Overall 25 students out of 51 answered to all questions.

4.1 On the collaborative project

Most of students really appreciated the new format of the Applied Optics course, namely in what concerns the project: they took it very seriously and they seemed to feel involved not only in collaborative problem-solving, but also in role playing, acting as real members of a company: they created company logos, referred to themselves using the name they had chosen for the company, and put quite a lot of effort in producing R&D projects and reports scientifically coherent and visually appealing. In general, the effort they put in the collaborative project was not detrimental for the other components of the course (theoretical classes, traditional laboratory activities, and synchronous online problem solving and simulation exploration) albeit not everybody was able to participate in all the synchronous sessions and to complete the simulation's test because of technical problems. The web forums did not catch their attention, for reasons that we will analyse hereafter.

In the group of students who answered to the enquiry, 72% said that they were satisfied or very satisfied with the Applied Optics 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 4).

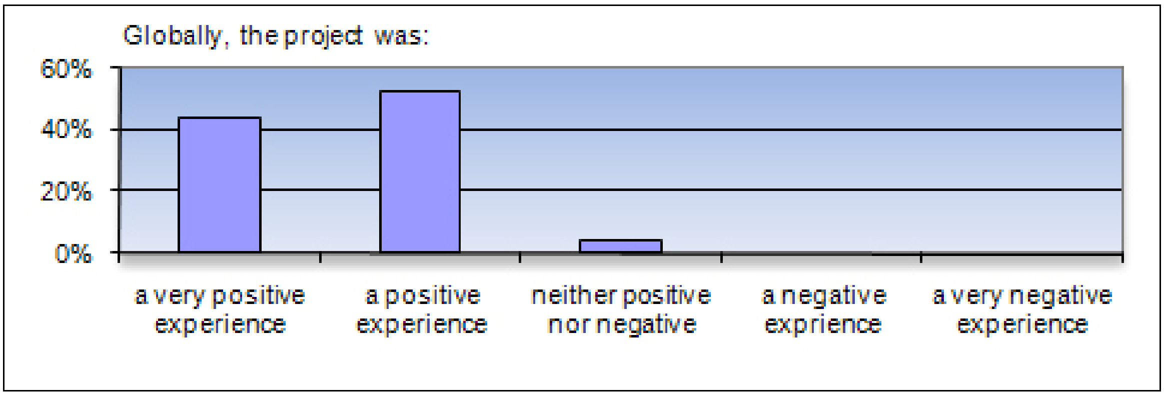


Figure 4 – Students' answer to the general question about the project.

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 seem willing to have more courses based on collaborative projects: having been asked to "grade" the statement "I would like to have other courses based on group projects", 20% said that they "completely agreed", 52% agreed, 16% neither agreed nor disagreed and 12% disagreed.

These differences could be related to the fact that for some of them the collaborative project made the Applied Optics heavier than other courses, namely for what concerns time expenditure: 36% of students said that time needed for project development made the course heavy and 8% very heavy (48% said that it was neither heavy nor light and 8% said it was light). This could be partially related to the fact that, not surprisingly, not all groups had good internal dynamics nor an equal participation to the work: commenting upon the statement "All group elements participated actively in the project development", 20% of students said that they completely disagree, 16% said they disagree, 12% said that they neither agreed nor disagreed, 32% said that they agreed and 20% completely agreed. Nevertheless, only one person in the group who answered the enquiry said that working in group had been a negative experience. It is also worth to point out that one of the students' most frequent comments was that groups were too big, and that the ideal number of members per group would be of three or four. Someone noted, anyway, that having to work in big groups was an asset, as it gave the chance or obligation to undertake a challenging task. Somebody else remarked that "the project allowed a real-life experience regarding organization, research and development" and other student pointed out that "the project allowed to acquire new skills, many of which are not even [formally] thought".

4.2 On e-learning

We also had a positive feedback from students on what concerns contents made available in the LMS: 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 the availability of high quality contents, resources and interfaces, produced in collaboration by teachers, instructional designers and graphic designers, is pivotal for successful e-learning in science and technology (Maneira et al., 2008). The evaluation of the synchronous online problem-solving and of the simulation with questionnaire is less clear. This is due to the fact that many students experimented technical problems with the LMS and this hindered them from participating to the online sessions and from completing the simulation. It would be one possible explanation for the wide range of opinions about these activities: when asked to rate the statement "Taking part in the online problem-solving class was useful" 66% of students said that they agreed or strongly agreed, 20% neither agreed nor disagreed, 16% disagreed, 4% said that it was not applicable and 4% did not answer.

Nevertheless we are prone to assume that for students who did not experiment technical problems the synchronous activities were positive: in the free comments, some learners pointed out that having more of these classes would improve the course, someone commented that the synchronous sessions are "very dynamic and this helps paying attention through the whole class" and someone else highlighted as an advantage of working online the fact that "it allows to draw schemes together, with each student adding parts during the exercise". These observations, together with results from previous surveys among Applied Optics students (Maneira et al., 2007), reinforce our opinion that online synchronous problem solving is a valuable strategy to foster learning in sciences. The situation was somewhat similar for the virtual diopter: technical problems remained unsolved during many days, prevented students from exploring the simulation and answering to the related test. As only two students posted positive free comments about the virtual diopter and as we lack of data from previous editions of the course, it is difficult to draw a conclusion about the usefulness of this specific simulation and about the efficacy of a questionnaire to guide its exploration. That notwithstanding, given the general consensus surrounding the benefits of simulations (Ranieri, 2005), when properly designed and used (Landriscina, 2005), we think that it is important to repeat this experience and to go forward in the implementation of a "virtual laboratory".

4.3 On web forums

As previously detailed, we had quite high expectations about the added value that web forums would represent for communication and learning, but by the end of the course we had realized that they were much more time consuming than we had supposed, that the majority of students could not be convinced to use them and that, in a course as complex and rich in activities as this one, they caused an overload both for students and teachers. Eventually the discussion forum did not even started, while the questions forum had a very low participation. Nevertheless we think that it is worth to analyse it and to report students' opinions, because they can drive to interesting observations and to important learning points.

Only 15 students out of 51 and one of the two professors posted at least one message in the forum, for a total of 33 posts; the professor posted a "welcome message" with instruction on how to use the system, but then he answered only once to the questions posted by students. We can see at least two reasons to explain this "failure". On one hand the stimulation/moderation of the forum had not been carefully planned in advance (Salmon, 2002; Ranieri & Rotta, 2005), the professors had not previous experience in forum moderation and they had very little time for it; furthermore the assistant professor had not really been involved in the design of this activity and this, added up to the lack of time, has probably induced scarce motivation. On the other hand we should consider that students spend on campus many hours a week, so they have plenty of occasions to interact directly, and they reasonably do not feel very much the need to communicate through a web forum. Still, twelve students (48% of those who answered the enquiry) said that they agreed with the statement that the "Forum for doubts" was useful, 36% said that they neither agreed nor disagreed and 12% said that disagreed. Six students (24%) said that the web forum helped in communicating with teachers, while 56% had no opinion, and 44% claimed that the forum helped communication among students. Even if we assume that students who answered favourably to the questions about the forum were the same who participated in it, it seems that there is a gap between the real use of the web forum and the positive assessment given by students. One hypothesis is that some of them are aware of the potential usefulness of forums, independently from the actual implementation reached in the Applied Optics course, because they are already used to this communication tool[6].

[6] A prerequisites survey run among students of the Applied Optics course 2007-2008 showed that 15% of them regularly participate in discussion web forums, 53% do it seldom and 32% never did it; 26% use web chats regularly, 47% seldom and 26% never used it. Virtually no one ever took part in an Internet community. These results are very close to those recorded in the prerequisite surveys run among students of the Applied Optics and Physics II in academic year 2006-2007.

It is interesting to notice that in spite of the lack of answers by professors and of the low interaction among learners in the web forum, a student commented: "[the web forum is useful because] when we have a last minute doubt and we have no time to go to the professor's office, we can post the doubt in the forum, so that another student or the professor can answer". At the other range of the spectrum of feelings towards computer mediated communication (CMC) we find the comment of a student afraid of the idea that online communication could replace face-to-face interaction. He/she wrote: "One thing that I find very good is the [face-to-face] communication between teacher and student existing nowadays [...]. If you (the teacher) remember well, most students did not take part actively to the web forum and preferred to talk to you directly. And I think it is excellent! I think that we should not loose face-to-face communication. Forum and e-mails, in my opinion, are very good when we cannot talk directly". Both observations make sense and may reflect different perceptions about CMC: some people see it as a way to improve communication, i.e. interaction among human beings, as it offers additional ways to exchange information; others showed their concern about jeopardizing communication and interaction, probably because they experience online communication as a poor surrogate of face-to-face conversations. In a blended-learning course it is desirable that students get to feel comfortable in both situations, and it could be helpful to state clearly since the beginning that the online communication tools are not supposed to substitute face-to-face interaction, but, on the contrary, they are meant to facilitate teacher-class and student-student collaboration. Additionally, it is interesting to record that, while in previous years nobody showed up during professor's office time, this year due to the challenges presented by the collaborative project students looked very often for the professor out of classes. Gathering together all these observation we concluded that even if in our experience the "Questions forum" had low participation, it is worth to include it in all courses supported by a LMS. It does not require a deep training and, once they get the habit to check it regularly and to write short posts, both professors and students can use it as a fast and valuable communication tool.

We cannot draw the same conclusions about the discussion forum (e-tivities), because it is much more demanding at all levels: organization, moderation and participation. In the light of this experience we think we can learn at least two important lessons:

- in a blended-learning course you have to carefully balance in-class/in-lab work and online activities, in order to avoid students' and instructors' overload;
- an instructor can be engaged in complex forum moderation only after proper training and careful planning of the web forum discussion: timing for questions and feedbacks, support and motivation strategies (Rotta and Ranieri, 2005; Salmon, 2002).

4.4 On students' assessment and grading

In the formal teaching-learning process, assessment and grading represent an important and tricky issue. In the Applied Optics course we made an attempt to articulate an assessment scheme that would account for the different activities (collaborative project, laboratory reports, synchronous problem-solving, simulation test and final exam). We did not ask specific questions about assessment in the final survey, but many students talked about it in the free comments, and seemed to appreciate the fact that the final grade did not depend only on tests and final exams. Nevertheless there were some complaints about the weight of the project in the composition of the final grade: as it was a quite demanding activity, someone suggested that it should have more relevance.

5 Professors' opinions and observations

Professors were very satisfied with the project-based teaching approach, because it promoted stronger participation and proactive attitude among students, both during laboratory activities and theoretical classes. They observed that, in contrast with what happens in the traditional experimental lab works, where learners tend to merely execute a protocol, when engaged in a real life project they switch to a different attitude, more creative and problem-solving oriented. As a consequence, students in the Applied Optics course developed a different relationship with the laboratory: they asked permission to use the installations out of scheduled time and clearly showed interest and enjoyment in using laboratory equipment; they felt that the lab was their own place, where they could develop their own project, and they started to work as real engineers. Furthermore, professors observed a healthy competition among groups, and they noted that many students felt proud for the work they were making and were eager to show it and to get due recognition. As a result, the quality of the final projects was generally good, with some groups presenting excellent works, denoting professional engagement and entrepreneurial attitude. The interaction between teachers and learners was also positively affected by the project, in fact, while in previous years nobody showed up during professors' office time, the challenges presented by the collaborative project pushed students to look very often for the professors out of classes, and to consider them consultants or advisors. For what concerns synchronous on-line activities, instructors confirmed the positive opinion expressed in previous years (Maneira et al., 2007): they found that this system, besides making easier the sharing of mathematical and graphical applications and allowing participants to attend the class from any place, helps the teacher to follow directly the work of each student without giving them the feeling of being "controlled". Instructors also noticed that the remote voice communication ensures a good human contact and a more "anonymous" participation which puts students at ease to talk freely.

On the whole professors were very satisfied with the results obtained with the constructivist pedagogical approach **(table 1)**. Compared to the previous academic year there was no significant difference in the average final grade (summative assessment), which reflects the performance in the area of theoretical knowledge and cognitive objectives related to lab activities. Our assessment system was not designed to evaluate attitudes, so this variable did not influence the grade. Nevertheless professors observed a major improvement in attitudes, compared to the previous years (i.e. ability to design an experimental protocol out of standard conditions, information search, proactive attitude, creativity in problem-solving, ability to cope with team-work).

	Objectives	Skills	Attitudes
Constructivist pedagogy	Construction of knowledge	• Search autonomy • Self-learning	• Proactive
			• Creative approach to knowlege* (problem-solving oriented)
	Contextualization and application of knowledge	• Laboratory protocol creation	• Entrepreneurial
			• Professional engagement* • Punctuality*
	Presentation of multiple and complex visions	• Knowledge management	• Team-work
			• Professional*
	Cooperative building of knowledge	• Communication (CMC tools and presentation techniques)	• Responsible
			• Engaged* • Competitive*

* Not expected results

Table 1. Results obtained in relation to the constructivist approach

As final remark professors pointed out that, although very positive under the pedagogical perspective, the project-base teaching approach was really demanding for them, for their time is divided into other courses, scientific work and management activities.

6 Conclusions

Collaborative projects and rich learning environments are two key features of constructivist instructional design. In the AO course students had to deal with many kinds of resources, instead of receiving a closed set of information, and this required knowledge management skills. Additionally, they needed to put in place knowledge, skills and attitudes for implementing the project within a group. This implied the possibility to learn together with the others, in a dynamic process, but also the need to develop a reflexive attitude towards one's own knowledge, in order to be able to explain, share, and possibly defend, one's ideas within the group. What is at stake in this teaching-learning approach is not only the ability to apply theoretical knowledge to a practical problem, which could be very well done in an individual assignment, but the chance/challenge to discuss different points of view and then make the best choice. Team-work promoted the distribution of responsibilities and roles within the team, which led to self-commitment in tasks according to each student's personality and capabilities. In most cases this led to enthusiastic engagement in self-learning and research activities.

Collaborative learning, although highly demanding in terms of time and interpersonal interactions, was welcomed by most of students, and even those who found it very heavy acknowledged its value and appreciated the opportunity to experience a real-life "R&D" situation. In the AO course e-learning and collaborative project-based learning were successfully combined, so that students could experience real-life situations. The good quality of the final projects shows that collaborative work was effective and that well designed interactive Learning Units offered a good scaffold for self-learning, precondition for proactive and creative approach to classes and laboratory work. As a whole, on-line resources and synchronous online sessions for problem-solving were highly appreciated. On the contrary, web forums activities did not catch students' attention, even though the use of this tool for "doubts solving" showed to have a good potential.

Recommendations:

- Collaborative project-work should be carefully planned, with milestones and objectives clearly stated since the beginning;
- Groups should not be bigger than four persons;
- Project reports must be written according to a specific format;
- Before opening a web forum, professors should be trained to moderate it and they should be aware that this activity can be very time-consuming;
- All the professors and assistants of a course should be involved in its design or at least to be introduced to its philosophy;
- E-learning staff should ensure necessary support and assistance to teachers and students;
- In any Department the assignment of management tasks should take into account that professors engaged in pedagogical innovations need extra time to develop teaching activities.

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Authors

Silvia Di Marco, Researcher, Faculdade de Ciências Universidade de Lisboa (FCUL, Portugal)
António Maneira, Researcher, Lab.eLearning - Faculdade de Ciências e Tecnologias, Universidade Nova de Lisboa (FCT/UNL, Portugal)
Páulo Ribeiro, Assistant Professor, Physics Dep. - FCT/UNL
M.J.P. Maneira, Senior Researcher, Center of Physics and Technological Research-FCT/UNL

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Edition and production

Name of the publication: eLearning Papers
ISSN: 1887-1542
Publisher: elearningeuropa.info
Edited by: P.A.U. Education, S.L.
Postal address: C/ Muntaner 262, 3º, 08021 Barcelona, Spain
Telephone: +34 933 670 400
Email: editorial@elearningeuropa.info
Internet: www.elearningpapers.eu