Experiment applying a learning methodology for projects in computer engineering classes that better adapts to ECTS credits and the EHEA

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Abstract

This article presents an experiment performed in academic years 2005-06, 2006-07 and 2007-08 on Project Based learning (PBL) as one of the tracks for students in Computer Graphics 2, an elective course in the third year of Computer Engineering, a degree offered at the Higher School of Engineering (ETSE) at the Universidad Autónoma de Barcelona (UAB).

To manage the documentation that was generated in the class, we used an LMS (Learning Management System) platform based on Moodle, which we have used in PBL and which enabled us to more easily manage the indicators and surveys to evaluate the students.

General area of interest of this innovation

This project involved adapting the PBL to a course which might give guidelines to professors on how to apply this methodology in their own course, regardless of the size of the groups. Likewise, an LMS platform based on Moodle was presented that makes it easier to manage documents (surveys, turning in homework assignments, teaching materials, posting marks) and generate evaluation indicators without the processing of this material being too much effort. The platform is available to any UAB professors who want to try it, regardless of whether or not they use PBL.

1. Objectives

1. The quest for new teaching methodologies in the realm of higher education is a recent topic of discussion at universities. The changes being experienced in the

information society have conditioned the students attending universities, leading us to believe that the profile of students today is neither better nor worse than in the past, rather it is different. Society demands professionals with not just knowledge but also abilities and skills. This has spurred an open debate in universities about the quest for new methodologies to convey information and motivate students' learning, with the overarching goal of educating professionals who are adapted to this new society. One of the methodologies that has appeared in recent years at universities is project based learning (PBL).

2. PBL is a cooperative learning strategy that focuses on the student as an individual member of a group, and it views learning as a communication process. In PBL, the project guides the entire process; it is vehicle that enables the students to acquire the skills needed to learn. The students are in charge of their own progress, and the professors mentor their work.
3. The PBL methodology fosters the following professional competences in students: teamwork, the group shouldering the responsibility, critical thinking, initiative and searching for information, organisation and handling of structured information, oral and written communication.
4. There are many reasons justifying the adoption of the PBL methodology (Font 2004):
   a) **Practical reasons:** PBL fosters teamwork, thus promoting student initiative and the quest for information. PBL encourages knowledge to be learned by understanding it, not memorising it.
   b) **Pedagogical reasons:** It enhances students' learning through research, which encourages students to use all the resources at their disposal.
   c) **Student-centred learning:** Students are active agents in their learning and in resolving the project. They have to learn how to manipulate unstructured information. There is also the potential for innovation.
   d) **Conceptual value:** PBL facilitates interdisciplinarity.
   e) **Formative as opposed to punitive assessment:** Students have to learn from their errors. Either the professor, classmates or the students themselves evaluate their own learning.

Bearing all of this in mind, the goals of the project are:

1. To study the PBL methodology in order to adapt it in courses in the Computer Engineering programme to see whether this methodology improves students' performance in terms of their level of knowledge and skills, following the guidelines of the EHEA.
2. To make this adaptation with a minimum (or better yet, zero) cost, so that it is not an excessive effort for either professors or students.
3. To define and implement an LMS (Learning Management System) platform to manage the documents electronically (homework, surveys, teaching materials, etc.).

Below is an outline of the specific experience with a course: Computer Graphics 2.

2. Description of the project

2.1. Point of departure

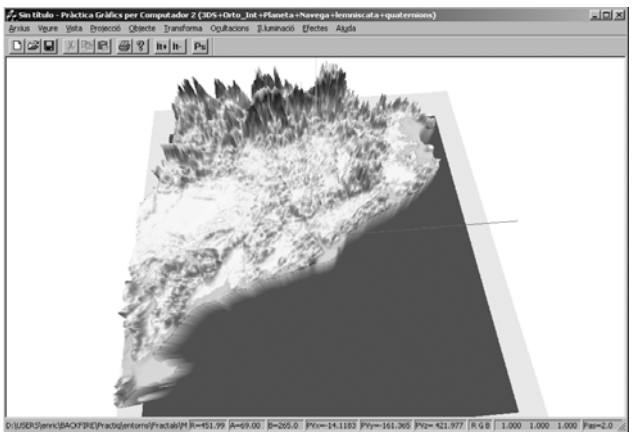
Computer Graphics 2 is an elective subject taught in the third year of the Computer Engineering degree programme taught at the Higher School of Engineering of the Universitat Autònoma de Barcelona. It is a class organised around 30 hours of theory, 15 hours of problems and 15 hours of practices. There are two groups of theory and problems (morning and afternoon) and six groups of practices, for a total of 150 students.

The students have already taken Computer Graphics 1, in which they learned the basic concepts of the subject. This course takes a deeper look at subjects related to modelling 3D objects, realism techniques and computer animation (Foley et al. 1993).

In the theoretical part, the course is organised as teacher-led classes (two hours per week). The problem part (one hour per week) is taught using Open Graphics Library, which is very often used in the world of graphic visualisation and videogames. Exercises are proposed to build objects based on primitive graphs, illumination exercises, textures, etc. The movement of rigid objects and articulated objects is also modelled within the part on computer animation.

The practices part of the class is organised into four laboratory sessions lasting 2.5 hours each. A graphic programming environment with minimal functionalities (Figure 1) is provide, based on which students add their graphic works gradually. At the end of the course, they turn in a single application with all their work.

Figure 1. Graphic programming setting with a topographic visualisation practice



The LMS platform (Caront 2008) and the website (GC2 2008) provide all the documentation: transparencies on the theory, documentation on OpenGL, instructions for the practices, the graphic programming environment, demos and corrected exams.

Based on the experience of teaching the course and the surveys administered to the students, we can reach the following conclusions:.

1. **Attendance at the theoretical classes drops over the course of the semester**. We believe that the fact of having provided all the teaching materials made attendance fall off. Nevertheless, this means that the students who do attend class are motivated.
2. **Attendance in the problems class did not drop so steeply**. The students consider posing, doing and resolving problems and the help with the practices in class useful and positive, which encourages attendance.
3. Each academic year, we notice that approximately **25 % of the practice groups show a significant interest in the course** and do more work than what is asked of them. These contributions enrich the course for the following academic years.
4. We can distinguish **different student profiles:** those who strictly want to *pass* the class because they are working or don't want to spend too much time on it, and those who want to *learn* and show a high level of interest in the course, as they are more highly motivated.
5. This is an elective course with many students (around 150), which can be taken in the third, fourth or fifth year of the degree programme, so the **students' knowledge and level of maturity fluctuate**.

2.2. Proposed tracks

In order to combine both student profiles, the course is defined into two different tracks: the TPPE (theory-problems-practices-exam) and the PBL track.

- **TPPE Track:** There are no teacher-led classes, so students only have to attend the problems classes (one hour per week) and the practice sessions (four 2.5 hour sessions). A term-long schedule of the topics to study is drawn up, students do the problems, attend tutorials to resolve their queries and take an exam at the end of the term.
- **PBL Track:** Two hours of the former teacher-led class are spent on tutorials for the PBL groups. Four groups of 30 students are organised (five sub-groups of at most six students). Each group has to sign up for one of the four timetables (M1, M2, T1, T2), in which M1 corresponds to the morning sessions of the odd weeks and M2 to the morning sessions of the even weeks. T1 and T2 follow the same pattern for the afternoon sessions. Therefore, each group of students has a tutorial with the professor every 15 days. This means that the PBL track can tutor up to 120 students (4 x 30) out of the total of 150 signed up for the course. The students pursuing this track attend the problems class but not the practice

sessions, and they do not take the final exam as their project is evaluated instead. In Section 3 we explain how this track works.

As can be seen, this double track does not mean a heavier teaching load for the professor compared to the previous course organisation. It does, however, mean a little more work in the tutorials and follow-up with the PBL groups, which is offset by fewer exams to correct, as the students on the PBL track do not take the final exam. Figure 2 shows the materials and activities for both tracks in the Caront platform.

Figure 2. Materials and activities in the Caront LMS platform for the courses two tracks: TPPE (left) and PBL (right)

3. Methodology

In this section we describe the methodology used with the students who took part in the PBL track. The students wishing to pursue the PBL track have to assemble into groups of four to six people – the students make their own groups. They sign up for one of the timetables (M1, M2, T1, T2), which corresponds to a tutorial with a professor every two weeks.

In the first group session, students are offered three projects, from which they have to choose the one they would like to do during the term. The explanation of each project is four to eight lines long. The proposal is generic, not very detailed and is followed by the learning goals that the professors want the students to deduce and use to resolve the problem.

Once they have chosen the project, the students have to consider and divvy up the goals and tasks among the groups members, also in the first session. Minutes must be taken at each meeting the groups holds (either with or without the professor), which should include the group's ideas, discussions and any agreements reached. These minutes must be handed in to the professor, which will enable them to keep track of the group work and how the individual students work as a group.

During the last week of class in the term, all the groups from the morning timetables meet in the morning session, and the same for the afternoon session, in order to defend their projects and hand in the documentation, which must include:

1. **Portfolio.** A report on the project which includes the goals, information checked, work performed and a small manual on the application developed. Students are given a template with a possible index at the start of the course.
2. **Presentation.** A document that contains the transparencies (at most 12) for the presentation. Students are given a template the start of the course.
3. **Computer application,** which corresponds to the solution to the project devised by the group. All the source files are turned in, and a demo version is made.

All of this documentation must be handed in electronically via the LMS platform (Caront 2008), and the portfolio is handed in on paper. The students make a 15-minute presentation for each project. The professor will have already drawn up an evaluation sheet where they rate the complexity of the project proposed by the group, their work capacity and the quality of the documentation, the presentation and the computer application. As a type of peer evaluation, the groups in the audience must also rank the best presentations by their classmates, without any points-based evaluation.

Twenty projects were posed, two of which are shown below. Other project explanations can be found in Martí et al. (2006).

3.1. Examples of projects

In this section we shall show two examples of proposed projects. In each example, the project explanations and teaching goals are shown. These goals are not shown to the students so that they do not condition their work. In the tutorial, the professor must fully encourage the group and only intervene or guide it when they see that the students are deviating far from the goals set in the project (Moust and Schmidt 1994).

The projects proposed by the professor aim to cover 60% or 70% of the syllabus of the course. There are 20 projects, including games, robot movement, airport simulations, amusement park rides, planets in the solar system and racetracks. Below, as examples, are the chess project and the simulation of an urban intersection with traffic lights and cars.

3.1.1. Project 1. Chess

1. Instructions:
   The Catalan Chess Federation hires you to make a graphic application that would visualise a chess match as realistically as possible, so that a match can be viewed like a film: in a continuous sequence or play-by-play forwards or backwards.
2. Learning goals:
   - **3D visualisation:** Definition of the board and the coordinates of each square on the board. Definition of different vantage points where the match can be watched.
   - **Modelling:** Modelling the pieces and the structure of the data to portray a configuration of pieces on the board.

- **Illumination:** Illumination of the scene, textures (pieces, board).
- **Movement:** Movements of the pieces on the board, resolving collisions in the tracks. How to eliminate pieces.

Figure 3. Design of the chess pieces. Board by a group of PBL students for Project 1

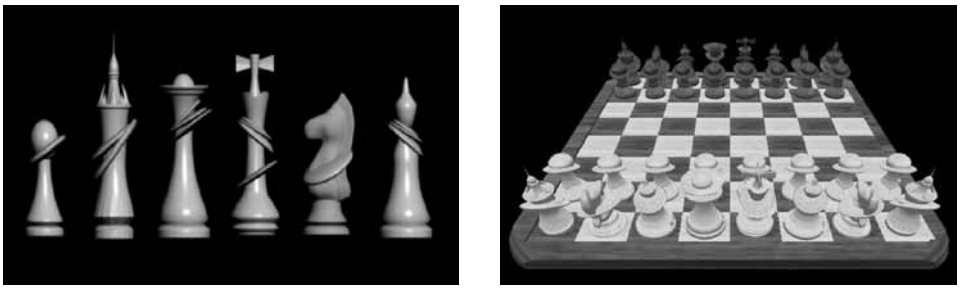


Figure 3 shows a sample from a PBL group from academic year 2005-06. In addition to achieving the goals, they made a personalised design for the pieces. In order to avoid collisions in movement, the pieces sink into one square and emerge in another one.

3.1.2. Project 2. Intersection

1. Instructions:
   The Barcelona Traffic Service asks you to develop a graphic application that enables them to simulate the interaction of roads with traffic lights so they can set the light times at each traffic light and the arrival of cars at the intersection. They want the scene to be portrayed as realistically as possible, visually speaking. The goal of this graphic tool is to verify that the traffic light timing is appropriate with regard to the frequency with which the cars arrive at the intersection in order to avoid congestion.
2. Learning goals:
   - **3D visualisation:** Definition of the types of cameras and their location.
   - **Modelling:** Modelling of cars and the intersection, valuing the fact that it can be configured.
   - **Illumination:** Illumination of the scene, ambient light, spotlights, sky.
   - **Movement:** Definition of the path of the cars and their arrival to the intersection.
   - **Additional concepts:** Queuing theory, arrival frequencies and service.

Figure 4 shows a project by a PBL group from academic year 2004-05, which enables the number of lanes at each stretch of the intersection to be set. The application defines different levels of detail of the scene. At the end of the simulation, statistics are drawn up.

Figure 4. Image of the application proposed by the students doing the «Intersection» project

3.2. Educational effort

For the TPPE track, the study effort for students is quantified in Table 1. It takes into account a 13-week term with one additional hour of individual study per hour of theory with a teacher, one additional hour for each hour of classroom problems, as well as two additional hours for each hour of practices with the professors, according to the evaluation of the Computer Engineering degree in the pilot project. Eighteen hours of study are added for the exam and 13 weeks. All of this yields a total of 141 hours, that is, 5.6 ECTS.

The PBL track uses project work. The effort for each student is shown in Table 2. It includes seven two-hour tutorials with the professor over the entire term, plus three hours per week of work searching for information, programming, etc. Attendance at the problems class is the same. As there is no exam, the hours to study for it are not included, and time is added to prepare the documentation.

In the PBL track, the students' educational effort in terms of the number of hours is lower, but we believe that it is higher quality time and effort on the part of the student. One of the additional advantages of the PBL track is that the work is done during the term without a final exam.

4. Results

In recent years, we have conducted anonymous surveys to assess students' opinion of the course, with a scale from one to ten points in three sections of the course: tuto-

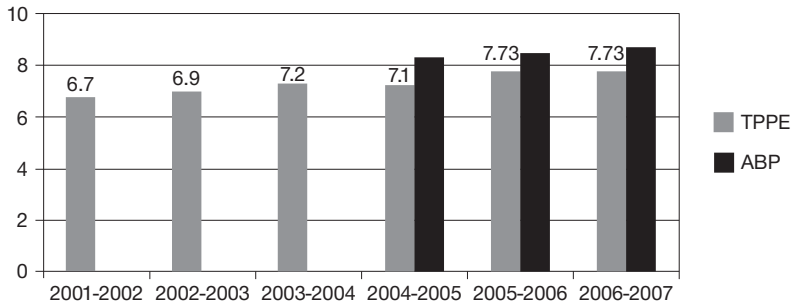
Table 1. Educational effort by students pursuing the TPPE track

	Professor-led class	Student study	Exam	TOTAL
Theory		4h x 13 = 52h	14h	66h
Problems	1h x 13 = 13h	1h x 13 = 13h	8h	34h
Practices	2,5h x 4 = 10h	5h x 4 = 20h		30h
			Total:	**130h (5.2 ECTS)**

Table 2. Educational effort by students pursuing the PBL track

	Professor-led class	Student study	Document	TOTAL
Theory	2h x 7 = 14h	4h x 13 = 52h	1h x 13 = 13h	66h
Problems	1h x 13 = 13h	1h x 13 = 13h		26h
Practices	2,5h x 1 = 2,5h			10h
			Total:	**102h (4.08 ECTS)**

Graph 1. Results of the surveys to rate the course (averages over 10)



rials with the professor, methodology and overall rating. The first surveys were administered minutes before the exam was to begin, which gave us a high number of samples. However, since academic year 2005-06, this survey has been conducted via the Caront platform [Car] and the students freely and anonymously responded after the end of the term. The results are shown in Graph 1.

For academic years 2004-05, 2005-06 and 2006-07, the students in the TPPE track were given the same survey as the previous years, while the PBL students were administered a different survey, although both had several questions in common.

We can see that the PBL students positively rated the experience, with scores over 7.5 out of 10. In the three years of this course, the ratings of students pursuing the TPPE track also rose. We can see a major drop in the number of responses from academic year 2006-07, because the course shifted from the third to the fourth year of the programme, and this led to a brief dip of 100 students (the students in the fourth year had already taken the class the previous year) and the elimination of the afternoon group.

5. Conclusions

Based on the proposal for a double track including PBL methodology in the course Computer Graphics 2, we can draw the following conclusions:

1. The choice of two tracks has prevented the professors from being overwhelmed, as might happened had all the students chosen the PBL track. Of the total of 150 students, between 50% and 75% chose the PBL track, and the others the TPPE track. We think it was positive to offer both tracks, as it has rewarded the initiative of the students pursuing the PBL track.
2. The lack of theoretical classes was not harshly criticised, given the fact that all the documentation was housed in the Caront LMS platform and the professors' availability in office hours was sufficient and appropriate.
3. Few PBL groups dissolved, and those that did so was because of a lack of time and commitment on the part of the members. These students joined the TPPE track without any problems.
4. The PBL students had a very positive perception of the figure of the professor. We believe that this class dynamic is more gratifying for the teachers and gives students more contact with them than in teacher-led classes.
5. We have noticed that the current evaluation system using marks quantifies knowledge but is not an evaluation of the skills developed in PBL. The students' files should also include an explicit assessment of the skills they developed, given the fact that the EHEA wants to foster these skills and competences.

Obviously, we believe that this experience cannot be extrapolated to all courses, classes and degree programmes. The professors must be familiar with the methodologies and experiences, as it is up to them to assess which are more appropriate for their course and to know how to adapt them. There is no unique or optimal methodology for everyone. In our course, PBL is positive for both professors and students. This experience, which can be improved on in the future, is our modest contribution to improving university teaching.

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Interesting links

- Innovation web site: http://caronte.uab.cat [2008]
- http://interact.bton.ac.uk/pbl/index.php: Index of universities, centres and subjects using PBL. [2008]
- http://dcc.uab.es/teach/a25011/c25011.htm: Website of the Computer Graphics 2 course. [2008]
- http://www.vidar.dk/vidar/vidpubre.nsf/: Master's in PBL applied to engineering problems taught at the University of Aalborg (Denmark). [2008]

Keywords

Project based learning, cooperative learning, LMS platforms, Moodle.

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Supplementary materials on the CD-ROM

Demonstration of the CARONT website: virtual tour of TPPE (theory, problems, practice, exam) and PBL (project-based learning) teaching methods for the Computer Graphics 2 course.

Project leader

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Presentation of the project leader

Lecturer at the UAB since 1992, with 22 years of experience as an educator. His areas of interest are graphic and interactive visualisation, computer animation and virtual and mixed reality, all applied to research and teaching. He is the coordinator of three elective courses: modelling and animation using Blender, basic and advanced courses on videogames and computer science and cinema, a cinema forum activity about social and ethical questions in computer science. The head of two teaching innovation projects (MQD2005 and UAB) and in the past three years, he has authored educational publications at national and international conferences and one publication in a major international journal.

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