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TEACHING ENGINEERING WITH AUTONOMOUS LEARNING ACTIVITIES

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This paper proposes several activities that encourage self-learning in engineering courses. For each activity, the context and the pedagogical issues addressed are described emphasizing strengths and weaknesses. Specifically, this work describes and implements five activities, which are: questionnaires, conceptual maps, videos, jigsaw and projects. These activities are applied in seven different knowledge fields and are conducted individually or in group depending on the nature of the subject and of the activity. Furthermore, this paper shows how the same activity can be applied in subjects of different years and how the implementation level changes, depending on the course in which it is conducted. The activities proposed have been introduced in engineering courses, but they can also be applied in any other knowledge field. Finally, the paper proposes four rubrics to assess three of the proposed activities (videos, jigsaw and project), being two of them for the project activity.

Keywords – Engineering education, Active learning, Autonomous learning.

1 INTRODUCTION

Autonomous learning, also called student-centered learning or flexible learning (Taylor, 2000), is a process through which individuals control their own learning and survive outside the sheltered environment of the classroom. Benson and Voller (Benson & Voller, 1997) defined learner autonomy as the ability to take personal or “self-regulated” responsibility for learning. It is widely theorized to predict academic performance. In the autonomous learning, the student can manage its own learning.

On the other hand, Chickering and Gamson define learning as (Chickering & Gamson, 1987), “it is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves”. Active Learning has been defined as any strategy “that involves students in doing things and thinking about the things they are doing” (Bonwell & Eison, 1991). This broad definition allows the usage of a very wide range of teaching and learning activities including collaborative and problem-based learning. In this work, however, we use the term more narrowly, as Paulson (Paulson & Faust, 2007), giving students a more active role in their learning process, but limiting the number of activities incorporated in the lecture context.

The paper provides some examples illustrating the application of such activities to different engineering courses, held in the 2010–2011 and 2011–2012 academic years. For each activity proposed, the authors discuss how it can be applied to engineering academic programs and how it improves the autonomous learning of

students. The paper demonstrates that these activities encourage learners' development towards autonomy by motivating and involving undergraduate students in class activities.

The main contribution of this paper is the development of five activities in seven areas of knowledge, from basic to higher cognitive complexity levels, starting in engineering subjects of the initial phase (first years), and ending on second cycles. This paper shows how the same activity can be applied in subjects of different years and how it has a different implementation level, depending on the course in which it is conducted. In first year courses, activities are more guided than in higher courses, where they are less patterned. Some activities are conducted in small groups, while others are individual. Additionally, this paper proposes four rubrics to assess the activities. It is worth noting, that the rubric also varies depending on the subjects' cognitive complexity level. We hope our experiences can be of interest to other teachers interested in experimenting innovative learning techniques.

The remainder of this paper is structured as follows. Section 2 reviews the background in this study. Section 3 presents our activities. Section 4 explains the methodology followed to assess the activities described. Section 5 presents the results obtained regarding students' satisfaction level for each one of the activities. Finally, Section 6 concludes the paper.

2 RELATED WORKS

This section describes and places in context the different active learning activities used in this study, which are questionnaires, videos, conceptual maps, jigsaw, and project based learning techniques. These activities are applied in different engineering degrees, such as Computer Science, Telecommunication and Aeronautics, in order to provide autonomous learning to the students.

2.1 Questionnaires

Questionnaires are widely used to guide self-assessment in learning processes. Specially, on those designed following cooperative learning, project and problem based learning; as well as e-learning courses. Some studies (Tousignant & DesMarchais, 2002) demonstrate the importance of self-assessment ability in PBL courses. Self-assessment is described as a structured process within which students realize the quantity and quality of her learning. Making use of questionnaires, students evaluate what they know or do not know.

On-line self-assessment (Ibabe & Jauregizar, 2010) takes advantage of electronic questionnaires which enable the combination of questions of different nature. They allow the combination of traditional textual questions, with multimedia questions. They also allow giving students more than one attempt to answer each question giving clues or providing the appropriate feedback.

Self-assessment questionnaires are widely used in engineering courses, for example the School of Information Sciences of the Pittsburg University developed the QuizPACK (Brusilovsky & Sosnovsky, 2005) system which generates and evaluates parameterized questions in the C programming domain.

2.2 Video

Videos are used in cooperative and self-learning activities to enhance students learning process. Several universities use video lectures (Haythornthwaite, 2001) since they offer some advantages, they allow presenting more material in less time, providing flexibility to students, and if they are used jointly with questionnaires, students become more interested and involved in their learning. In some cases videos are also used in self-evaluation activities (Duroc, 2012), helping students to correctly solve online questionnaires.

The Massachusetts Institute of Technology (MIT) provides audio and video lectures (Massachusetts Institute of Technology, 2015) for different disciplines, as Electrical Engineering or Computer Science. Another interesting initiative is led by the Maastricht University, which takes advantage of short video fragments (Maastricht University, 2015), arranged around relevant themes of a course, to enhance learning.

On the other hand, videos are used in cooperative learning activities, such as the jigsaw (Makkonen, 2012). In this case, the videos are recorded by the students. Usually, each group expert generates a video with the explanation of the theme which is in charge, and makes the video accessible to the other members of her group through a wiki, digital campus, or web page.

Finally, another example of activities which makes use of videos is the development and assessment of generic skills, such as the oral communication, or the work group.

2.3 Conceptual Maps

A conceptual map can be defined as a graphical representation of the logical relations between the concepts of a topic in the form of propositions. These concepts and propositions are organized to form hierarchies of different levels for better conceptual understanding. Using conceptual maps, students discover the different relations between concepts and discuss about them.

Originally, the concept mapping was developed as an educational tool for representing general knowledge to organize and communicate information (Novak & Gowin, 1984; Novak & Cañas, 2009; Cañas et al., 2004). However, there are many domains in which the concept mapping can be used. They can be used as a “brainstorming” tool, in the system design process (Kramer, 1990), to help students understand the structure of the curriculum, the relationship between courses, and the material within a course (Cornwell, 1996; Morsi, Ibrahim & Williams, 2007) and to evaluate students’ understanding.

Focusing in the student evaluation, Tokdemir in (Tokdemir & Cagiltay, 2010) propose the use of the concept map technique to better visualize and discover all the connections between the concepts of Computer Engineering. Tokdemir applied to the concept mapping a new paradigm called “Goal-Question-Concept” based in the well-known “Goal-Question-Metric” (Basili & Rombach, 1988). Darmofal (in Darmofal, Soderholm & Brodeur, 2002) used concept maps and concept questions in aerospace engineering at the Massachusetts Institute of Technology (MIT), focusing on a set of concepts in aerodynamics and thermodynamics, with promising results in oral examinations with aerodynamics students. Knight et al. (Sims-Knight et al., 2004) also use concept mapping to evaluate students’ understanding, but in this case for the design process.

2.4 Jigsaw

The Jigsaw (Aronson, Blaney, Stephin, Sikes & Snapp, 1978) is a cooperative learning technique that assumes that students are organized in small groups for the acquisition and presentation of new material, which is equitably distributed in parts reasonably independent. After studying individually their area of expertise, the experts of the different groups meet to discuss their topic and solve doubts, returning right after to their groups to teach the topic to their group mates.

The Jigsaw method is extensively used for teaching in different domains and with significant positive effect on students’ performance. For example, Pow-Sang (Pow-Sang & Campos, 2009) used jigsaw in a software engineering course in order to improve the students’ knowledge about class diagram analysis. The Pow-sang students improved their performance, comprehension and learning of the topic after the cooperative work was finalized. Tahir in (Tahir, Othman & Yahaya, 2011) applied jigsaw in Electrical Engineering Courses yielding good results in the students’ achievement and performance. Both studies revealed that the jigsaw technique has positive effect in the students learning process and their achievements (Tahir & Othman, 2010; Huang, Huang & Hsieh, 2008; Holloway, Tilleman, Macy, Parkman & Krause, 2008; Carpenter, 2006; Pozzi, 2010).

2.5 Project-Based Learning

Project-Based Learning (PBL) (Blumenfeld, Soloway, Marx, Krajcik, Guzdia & Palincsar, 1991; Buck Institute for Education, 2015; Solomon, 2003) is described as a model that organizes learning around projects, which are complex tasks that lead students to perform design, problem solving, management and planning tasks, resulting in realistic products or presentations. Students work relatively autonomously in groups to solve challenging questions or problems, over extended periods of time. The teachers’ role is to guide students in this process, providing feedback to them in order to improve the quality of their work.

A great variety of PBL activities can be found in the literature. In (Thomas, 2000), Thomas describes the features that a project must have. It must be central to the curriculum, intended to teach significant content, focused on problems that drive students to struggle with main concepts of the discipline. Projects must be realistic, leading students to constructive investigation, critical thinking and giving them autonomy and responsibility. Different universities, such as the Aalborg University or the Universitat Politècnica de Catalunya, more specifically the Castelldefels School of Telecommunications and Aerospace Engineering (EETAC) designed their bachelor

programs following the cooperative and project based learning models. They are interested in providing an active role to the students, while redefining the role of teachers in the learning process.

The PBL methodology enables students to work cooperatively, improving collaboration, management, decision making and communications skills.

Nowadays, PBL is used in different ways (Martínez-Monés, Gómez-Sánchez, Dimitriadis, Jorrín-Abellán, Rubia-Avi & Vega-Gorgojo, 2005; Martínez, Herrero & De Pablo, 2011). On one hand, there are the schools that have defined their bachelor programs following the PBL model; while other schools use PBL occasionally, only in specific subjects of a degree. Moreover, it is used in different ways depending on the subject, for example depending on the previous experience of students in developing projects. Usually, the projects in first courses are really guided, supervised by teachers, have short duration and are conducted by small groups of students, while in the last courses, projects are more ambitious, less guided, developed by large number of group students, and usually has a duration of a complete semester. It is worth noting; that using PBL, students (Buck Institute for Education, 2015) are more motivated, gain a deeper understanding of concepts and develop workplace skills, like design, problem solving, critical thinking, decision making, management and research.

3 ACTIVITIES

This section describes the development of all the proposed active learning activities in our courses. For each activity a brief description and its assessment method is provided. We show five different activities, two of them are individual, while the rest of the activities are done in group.

The activities done in group benefit to the students, not only because they provide a more dynamic and entertaining way of learning, but also because they acquire more knowledge and skills, and their learning process becomes more useful. On other hand, individual activities encourage the independent study promoting the autonomous learning. Table 1 shows the application scenarios (degree and subjects) for all the activities described in this paper.

<i>School name</i>	<i>Degree</i>	<i>Number of students</i>	<i>Course Level</i>	<i>Credit course</i>	<i>Subject</i>
Barcelona School of Telecommunication Engineering (ETSETB-UPC)	<i>Telecommunications Engineering</i>	400	1A	4 credits	<i>Introduction to computers (IO)</i>
	<i>Telecommunications Technologies Engineering</i>	400	1A	6 ECTS (150 h)	<i>Fundamentals of computers (FO)</i>
	<i>Audiovisual Systems Engineering</i>				
	<i>Electronic Systems Engineering</i>				
	<i>Telecommunications Systems Engineering</i>				
	<i>Telematics Engineering</i>	240	1B	6 ECTS (150 h)	<i>Object-oriented programming methodology (MPOO)</i>
	<i>Engineering of Telecommunications Technologies</i>				
	<i>Audiovisual Engineering</i>				
	<i>Electronic Systems Engineering</i>				
	<i>Telecommunications Systems Engineering</i>				
	<i>Telematics Engineering</i>				
Castelldefels School of Telecommunications and Aerospace Engineering (EETAC-UPC)	<i>Air Navigation Engineering</i>	120	1B	12 ECTS (300 h)	<i>Aerospace Technology and Air Transport and Informatics I (TAE-INF1)</i>
	<i>Telematics Engineering</i>	20	3A	3 ECTS (75 h)	<i>Telematics Services Intensification (IST)</i>
	<i>Telecommunications Systems Engineering</i>	25	3A	3 ECTS (75 h)	<i>Software Engineering Project (PES)</i>

Table 1. Sceneries of our activities

3.1 Developing a questionnaire for teaching purposes

A questionnaire is a method for the elicitation, recording, and collecting of information. We use this tool to teach some topics in the IO and FO subjects. In this subsection, we describe the application of questionnaires in the IO subject. For FO subject the activity is the same, changing the questions of each questionnaire. The questionnaire activity supports the development of the autonomous learning skill.

The IO subject is organized in six topics. For each topic, we have six questionnaires. These questionnaires are in the virtual platform called atenea that use the free source e-learning software platform known as moodle (Moodle, 2015). Each questionnaire has seven questions of closed questions or multiple answer questions. In the closed question, the student can be answered with either a single word or a short phrase; while in the multiple answer questions the student has to select the best possible answer (or answers) out of the choices from a list. Figure 1 shows one example of a closed question. The student has up to three attempts to answer each question. The question's answer can be correct, partially correct or incorrect and for each case the mark obtained is different. For example, if an answer is partially correct the question is graded with the half of its score.

Figure 1. Question example – Flow control questionnaire

The final mark of a questionnaire is the accumulated grade for each question. A student can answer the same questionnaire as many times as desired. The feed-back to the student is an immediate process.

3.2 Making a video

Videos are used as a cooperative learning activity in the FO, MPOO, IST and TAE-INF1 subjects. This activity supports the development of oral communication generic skill.

In the FO subject, the students make a video following a guideline. The video includes explanations of new basic concepts specified in the guideline, which have not been taught in class. The duration of the video cannot exceed 15 minutes. Initially, the whole class is organized in small groups of four students. Each member of a team individually studies the basic concepts required for to share his/her ideas with the other team members. This aspect promotes the cooperative learning because the students pursue common goals, while being assessed individually. Finally, each team makes an educational video.

In the MPOO, TAE-INF1 and IST subjects the students individually make videos in the context of the jigsaw activity. See more details in subsection 3.4.

3.3 Conceptual Maps

This activity is conducted in the FO, IO and MPOO subjects, supporting the development of autonomous learning skills.

A conceptual map is a graphical tool for organizing and representing knowledge (Novak & Cañas, 2009). They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts represented by connecting lines linking two concepts. In the elaboration of a conceptual map is necessary to have an application context where students previously have identified from 15 to 25 concepts associated with the context. These concepts are listed, ordered from the most general to the most particular concepts. The least general concept is written at the bottom of the list. The next step is the construction of a preliminary conceptual map using a computer software program, for example the IHMC CmapTools (Cañas et al., 2004). Each student designs its own conceptual map in an extra hour of class. Figure 2 shows an example of a conceptual map developed in the FO subject where the application context was: *the function call by reference or value*.

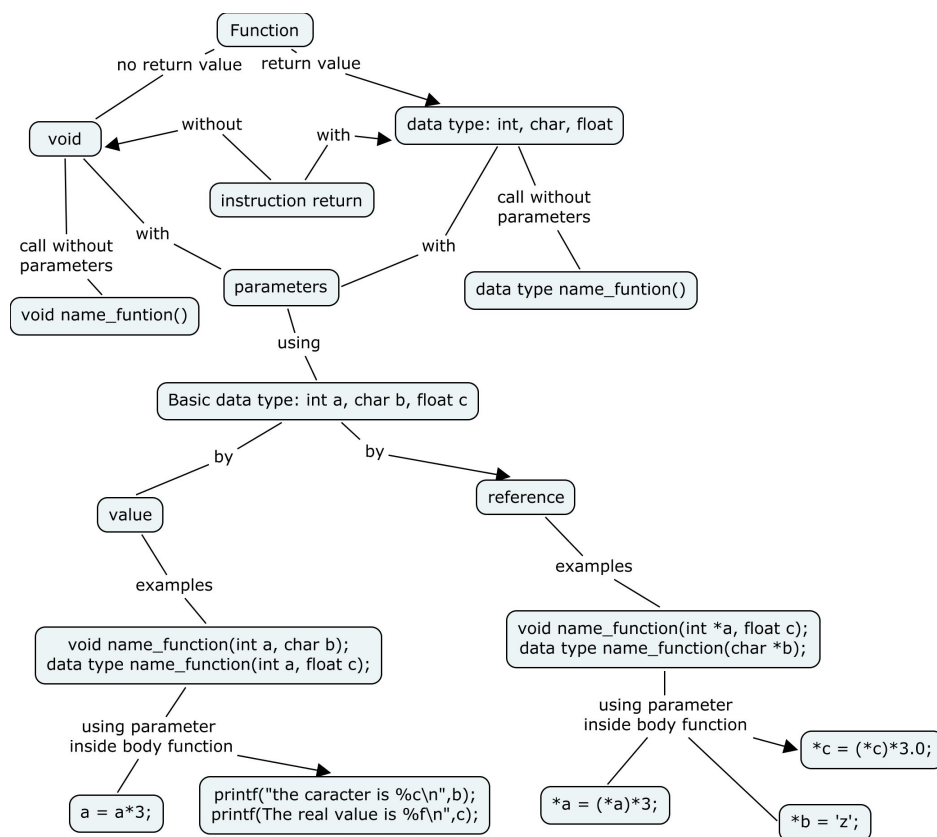


Figure 2. Example of concept map - Function call in C

3.4 Jigsaw

This activity is used in the IST, MPOO and TAE-INF1 subjects, supporting the development of autonomous learning, oral communication and work group skills.

In the MPOO subject, the jigsaw is used to study the Java collections theme, which consists of sets, lists and maps. Students are organized in groups of three and each one of them becomes responsible of one of the themes. They first individually study the assigned theme. Right after, a meeting of experts takes place to put in common the knowledge acquired and to solve the doubts raised. In this meeting, which takes place in the classroom, the teacher also participates. After the meeting, each expert prepares a video for the other two members of her group presenting the theme together with some guided exercises, as well as the correspondent

solutions. Then, the students watch the videos and make the exercises prepared by the other two peers. Finally, each group meets up to clarify doubts.

In the TAE-INF1 subject, the jigsaw is used to work the data structures, files and functions themes. Its operation is the same as for the MPOO subject.

In the IST subject the jigsaw activity is used to acquire knowledge for two technologies: Installation systems (Smith, 2011) and P2P Networks (Barkai, 2002). Just as in the MPOO subject, students first individually study the assigned theme. Then, an experts' meeting takes place to put in common the knowledge acquired and to solve doubts. After the meeting, the experts of each theme jointly prepare a presentation and a simple demo for their peers. Finally, in a meeting, in class, during one of the project sessions, they explain the acquired knowledge to the rest of the peers using the presentation and demo prepared.

3.5 Project-based learning

The project activity is conducted in MPOO, TAE-INF1, IST and PES subjects. It supports the development of the work group generic skill. This section describes how the project activity is designed and implemented in four subjects, organized according the year of teaching. This classification is motivated because projects in initial courses are more guided, shorter in time, carried out by smaller groups of students (to facilitate their management), and less ambitious than in subjects of last courses. Therefore, its design and implementation is different as detailed next.

3.5.1 First years projects

In the MPOO subject, the students carry out a project in groups of two, during the second part of the course, in which they place together the object oriented programming (OOP) skills learned throughout the course. Typically, in the project the students develop a Java application, in which they deal with object oriented design and programming (classes, objects, encapsulation, inheritance, polymorphism and exceptions) in depth.

The project is organized in three major phases. In the first one, the students perform the design of the application. To this end, the faculty provide to the students a detailed requirements' analysis, together with the application requirements' document, which clearly define the scope of the project. In this first phase, the students define the use cases, conceptual model, as well as the class and sequence diagrams. During the project is important to monitor the progress of the groups. To this end, the faculty gives to each one of the groups feedback every week, during the laboratory session.

The second phase entails the implementation of the application based on the design previously done. In this phase the students implement the classes and objects of the application. They also implement inheritance and polymorphism. In the last phase, the students define and handle the exceptions in their application. It is worth noting, that during the whole project, the faculty monitor the progress of the different groups giving feedback each week. Since MPOO is a subject of the first course, and it is the second programming subject, the students pursue in the degree, the project is really guided by the teachers.

Some examples of projects done in the last courses are: a social network, a music management application and a card game application.

The students of the TAE-INF1 subject also carry out a project during the second part of the semester, but in this case in groups of 4. As in the MPOO subject, the project consists of a sequence of steps including the design of the experiment (aeronautics concepts), the simulated flight test (aeronautics concepts) and the post-processing of the acquired data by means of a MATLAB program (data structures, files and functions concepts), resulting in the presentation of the in-flight aerodynamic characteristics of the airplane (plotting concepts). One example of this project for the last semester was to design and perform (through flight simulation) a flight test to determine the in-flight aerodynamic characteristic curves for the longitudinal coefficients CL and CD of an aircraft, specifically the Cessna 172.

3.5.2 Last years projects

In the IST subject, the students conduct, during the whole semester, a project in groups of five or six in which they place together the skills that they learn throughout the course.

Typically, the project is a secure distributed multimedia application, in which the students deal with its design and implementation. The project is organized in two major phases. In the first one, the students perform the design of the application. To this end, they first perform a detailed requirements' analysis, and produce the application requirements' document, which clearly define the scope of the project. In this first phase, the students also define the use cases, class diagram and sequence diagram. This work is presented the fourth week of the semester. The teacher in charge of the design activities gives, during the presentation, to each group the appropriate feedback. Then, the groups improve the design according to the teacher comments. Students also perform planning tasks in the project and determine the student responsible for managing each task. The second phase of the project entails the implementation of the application based on the design previously done. In this phase the groups perform two presentations of the work done. The first one takes place the eighth week of the semester in which the students present a first prototype of the project and an analysis report. In this presentation all the teachers provide feedback to the students. According to the feedback received, each group redesigns the application, if needed. The final project presentation is done the last week of the semester. One week before the presentation the students deliver the project memory. It is worth noting, that during the whole project, the faculty monitor the progress of the different groups. To do so, they students deliver two monitoring templates each week, one for the work done and another planning the work to do during the next week. Since IST is a subject of the last course, and the students have a lot of experience in developing projects, the project is really open and the students work autonomously.

An example of project is a Video Conference System, which has the following characteristics: secure, in real time, with video messages. The technologies used in this project are: Video Conference, video messaging, application with presence system, users' registration, web interaction, and security.

The PES project is conducted in groups of four. It uses Kanban (Kniberg & Skarin, 2010) and Test-driven development (TDD) (Beck, 2002) as software development methods. Each part of the project (MVC) has to be tested in a proper way according to the development framework used. To test the Model and the Controller the students use the JUnit (Unit testing with Junit, 2015), while to test the views they use Selenium (SeleniumHQ, 2015).

On the other hand, the Kanban method is applied to the Agilezen project management software (Agilezen, 2015). Agilezen has a free on-line version where the students should login and invite the professor to follow the management of the project. In that way, the students practice these two concepts involved on the course. Example of a typical projects are On-line stores (clothing store, surf store, etc.) or hotel booking web applications.

The organization is similar to IST, students work autonomously in a big project, which leads them to a realistic product.

4 ASSESSMENT OF THE ACTIVITIES

This section describes the assessment method used to evaluate the activities presented in this paper. Note, that the questionnaire and conceptual maps are activities that are not evaluated in the IO, FO and MPOO subjects.

4.1 Making a video

This activity represents the 5% of the final grade in the FO subject, obtained from the evaluation done by teacher, using the rubric described in Table 2.

Guideline	Description
Individual work (2.5 points)	1. The student has made a good and effective presentation of the subject. He has done a rigorous search in the literature. He has spent time studying the issue. 2. The student did not understand some topics. 3. The student has technical deficiencies in the subject. The references checked are not clear.
Group work (2.5 points)	1. The organization of the group is good. Each student performs the assigned tasks. 2. The group has some problems in the organization.
Structure presentation (1.0 point)	1. The team members get introduced and greet the audience. 2. There is an introduction which briefly describes the main ideas to be developed in the presentation. 3. Team members develop each one of the main ideas. It is obvious when one topic is over and the next begins. 4. Team members summarize the main points of the presentation.
Technical topics (3.0 points)	1. The group has explained the whole theme (all topics). 2. The group has not explained some topics.
Originality of presentation (1.0 point)	1. The presentation is entertaining and enjoyable. 2. The presentation is boring.

Table 2. Rubric to evaluate the video activity

4.2 Jigsaw

The jigsaw activity represents the 10% of the final grade in the IST subject. It results from the evaluation done by teacher and the students using the rubric presented in Table 3. Moreover, it has an impact in the project qualification, since the technologies studied in the jigsaw activity are used in the project. For example, the last deliverable of the IST project includes an installation system for the secure distributed multimedia application developed.

Criteria	Description	Done	
		Yes	No
Structure (2.0 points)	The presentation is structured.		
	There is an introduction that briefly presents the main ideas to be developed during the presentation.		
	Each of the main ideas has been developed in the presentation.		
	The audience clearly notices when one part of the presentation finishes and the following starts.		
Contents (3.0 points)	I have understood the contents of the presentation.		
	The relevance and usability of the presented subject has been clearly justified.		
	The different parts of the presentations are well tied, I have followed the presentation.		
Demo (3.0 points)	The demo helped to better understand the theoretical concepts presented.		
	The examples selected in the demo have been illuminating.		
Verbal language (1.0 point)	The public speaker is a good communicator.		
	He/she clearly explains the main concepts of his/her theme.		
	He/she uses short sentences.		
	He/she uses pauses to clearly determine when he/she moves forward to present a new idea.		
Timing (1.0 point)	His/her voice tone conveys confidence and security.		
	The time has been adequately distributed between the theoretical explanation and the demo.		
	The presentation has tight to the expected timing.		

Table 3. Rubric used to evaluate the quality of the presentation done in the jigsaw activity

4.3 Project-based learning

4.3.1 First years projects

In MPOO the project represents the 30% of the final mark of the subject. It is graded according to the following aspects:

- Project development: This part represents the 20% of the final mark and it is graded by means of three deliverables, according to the three main tasks conducted during the course: design (5%), core implementation (10%) and exceptions implementation (5%).
- Project extension: This part represents the 10% of the final mark and it consists of an individual evaluation done by each member of the group, in which he/she has to add a new functionality to his/her project. It is done in the laboratory with a PC and has one hour of duration. This individual extension has as main objective to verify that the project has been carried out by the two members of the group.

The TAE and INF1 project represents the 40% of the final mark for each subject. The project is graded as in the MPOO subject plus an individual test, which represents the 10% of the final mark. The project development represents the 20%, including a preliminary report and the final implementation which is evaluated considering the quality criteria shown in Table 4. Finally, the project extension represents the 10%. Note that the assessment includes a theory test (10%) due to the nature of the subject.

4.3.2 Last years projects

4.3.2.1 IST Project

In IST, the project represents the 60% of the final mark of the subject. It is graded according to the following schema:

- Requirements presentation: This part has not weight over the final mark of the project. It takes place during the fourth week of the course. Each group presents the requirements analysis and a first version for the system design. The same day of the presentation each group deliver a document with the planning for the project, which includes a first specification of the tasks to do during the semester, its deadline, and the responsible for each task.
- First project presentation and analysis report: This part represents the 40% of the final mark of the project and it is done during the eighth week of the course. Each group presents the system design (final), the specification of the protocols and algorithms for the application and a first prototype. The same day of the presentation each group deliver a report of the analysis performed (estimations or simulations of the system).
- Final project presentation, project memory and poster: This part represents the 60% of the final mark of the project and it is done during the last week of the course (week fifteen). Each group presents the final system design (focusing on the changes done in relation to the first project presentation), one demo of the system (in which the teachers verify if the system requirements are achieved) and a poster describing the system.

One week before the presentation of the project each group delivers the project memory. The same day of the presentation each group deliver the installation system for the secure distributed multimedia application.

During the whole semester, the faculty monitors the project development by means of the templates shown in Figures 3 and 4.

The first template (see Figure 3) is used to plan the tasks to be done by the different members of the group every week; while the second template (see Figure 4) summarizes the achievements obtained by each member of the group and the number of hours spent.

Task: _____
Brief description of the task: _____

Responsible of the achievement of the task (one student): _____
Members of the group involved in the development of the task: _____

Estimated time (in hours) to achieve the task: _____

Figure 3. Template to evaluate the tasks performed each week

Quality Criteria (points)	Good (all points)	Fair (half of the points)	Low (0.0 points)
Functionalities (4.0 points)	The final program is a user <u>menu</u> able to read from different files names the log of a flight. The program is able to <u>plot the path</u> (2D+Vertical), to create a <u>KML</u> file with the flight and <u>plot the 3 aerodynamic curves</u> (CL, CD and CL+CD) correctly.	<u>One</u> of the previous five underlined functionalities is not working.	<u>Two or more</u> functionalities are not working.
Fulfillment (2.0 points)	The 11 functions and 7 structs of the program are defined <u>exactly as requested in the specifications</u> (see project summary). The expected outputs (path and curves) are <u>correct</u> and include file data conversions (latitude, longitude, etc.)	1. At most <u>one function</u> and <u>one struct</u> do not exist or do not fulfill the specifications, or 2. The expected outputs (path and curves) shown are <u>not correct</u> .	1. More than <u>one function</u> or <u>one struct</u> do not exist or do not fulfill the specifications, or 2. The expected outputs (path and curves) are <u>not shown</u> .
Friendliness (2.0 points)	Execution is friendly even for a non-expert user: Menu <u>options</u> are clear. Plots are always grouped together in <u>one window</u> . Units have been <u>converted</u> to the International System of units. Plots always show <u>legends, units and title</u> . Output and error <u>messages</u> are always given to the user.	<u>One</u> of the previous five underlined items is not given.	<u>Two or more</u> friendly items are not given.
Code (2.0 points)	Program code is well organized and <u>indented</u> . Variables <u>names</u> are clear. <u>Loops</u> always finish, even when unexpected input is given. Code is <u>robust</u> and <u>errors</u> (like nonexistent file names, incorrect time intervals, etc.) are controlled by the program.	<u>One</u> of the previous five underlined items is not given.	The program code is not clear, has problems on the execution and is not well organized.

Table 4. Rubric used to evaluate the quality of the final report and the code delivered in the project activity of TAE and INF1 subjects

Student Name: _____	
Task Name: _____	Devoted Time: _____
Task Name: _____	Devoted Time: _____
Task Name: _____	Devoted Time: _____
Student Name: _____	
Task Name: _____	Devoted Time: _____

Figure 4. Template to summarize the achievements that each group member has obtained in a period

4.3.2.2 PES Project

The PES project represents the 40% of the final subject mark. This percentage is divided in two parts: 30% goes to the project evaluation quality (fulfillment, efficiency, robustness, etc.), and the remaining 10% goes to a group evaluation.

The group mark criterion is evaluated using the Team Work Controls (TWC). TWC are individual exams to check if all the group members are aware of the project and its technologies. Typical questions of these exams are: time of the last group meeting, how many classes have the Web application model and the responsibility of each class, etc. The TWC marks average for the different members of the group represents the 10% of the group evaluation.

On the other hand, the project quality evaluation criterion is shown in Table 5.

Quality Criteria (points)	Good (all points)	Fair (half of the points)	Low (0.0 points)
Correct and Fulfillment (4.0 points)	All the functionalities described in the functional design specification are fulfilled. The students choose what sort of project they are going to develop. To this end, they have elaborated the Functional Design Specification document precisely specifying what they want.	Half fulfillment of the functionalities described in the functional design specification are given.	Fulfillment of less than a half of functionalities described in the functional design specification are given.
Efficiency (1.0 point)	There is not unnecessary code or redundant processing code. Reusable components wherever possible are used. Error and exception handling at all layers of software are used (such as the user interface, logic and data flow). Best keywords, data types and variables are used. There is no redundancy in database.	<u>One</u> of the previous five underlined items is not given.	<u>Two</u> of the previous five underlined items is not given.
Robustness (1.0 point)	The application resists to all the errors. Creating automatic test suites for your application is a good way to make it robust. Play framework provides a plug-in, called "Cobertura", to calculate the percentage of code accessed by tests.	If your applications resists to all the errors and your testing coverage is under 80%.	If the application crashes completely during the presentation or during any test.
Friendliness (1.0 point)	The Web application user has had no doubt at any time on how to interact with the Web application.	The messages and information of the Web application are good enough, however, on one or two times I have had some doubts about what to do or how to do it.	The professor has doubts about how to interact with the application (what it's asking or how to interpret the data showed) on three or more times.
Documentation and organization (1.0 point)	The application code is indented. Each method and its input and output parameters are well documented. The delivered solution is well organized: The Web application and android application are in different folders and clearly separated. In addition, the student has added a technical report illustrating technical details and a user manual (if necessary).	<u>One</u> of the previous three underlined items is not given.	<u>Two</u> of the previous three underlined items is not given.
Extras (2.0 points)	The students offer two extra functionalities to their project outside FDS.	The students offer an extra functionality to their project outside FDS.	No extra functionality is given.

Table 5. Rubric used to evaluate the quality of the PES project activity

5 RESULTS

One way to measure the effectiveness or quality of an activity is through student feedback. There is general agreement that students can provide valid observations and judgments on a wide range of aspects of teaching (Marsh & Roche, 1997). A survey among the students was carried out to find out their activities' satisfaction level and to identify potential gaps. The survey was created online using the questionnaires offered by Google Docs. The questions included in the students' survey are shown in Table 6. The questions are evaluated within a scale from 1 to 5 (from totally disagree to totally agree). Each activity of the survey was answered, approximately, by the 40%-60% of the students in each subject. Figures 5, 6, 7, 8 and 9 show the average rating questions obtained for each activity done in the course 2011-2012. The results showed are slightly better than those obtained for the course 2010-2011.

Question	Points
Q1.	<i>With this activity, I've learnt and understood the contents associated with the subject.</i>
Q2.	<i>With this activity, I've significantly progressed in the achievement of generic competencies defined in this course.</i>
Q3.	<i>The use of TIC tools, to do this activity, has improved my learning process.</i>
Q4.	<i>Overall, I was satisfied with the quality of this activity.</i>
Q5.	<i>The information materials/methods provided for this activity helped me to learn autonomously.</i>
Q6.	<i>The activity does in non presencial tasks were appropriate for the course objectives.</i>

Table 6. Components of the course and teaching evaluation and improvement: 6 open questions

The best valued activities for Question 1 (With this activity, I've learnt and understood the contents associate with the subject) are conceptual maps and questionnaires, as shown in Figures 5 and 6.

We can observe that these activities are the ones that most contribute to the contents' learning process, supporting in turn the development of autonomous learning skills. It is worth noting that this activity is suitable for first years' subjects, since students has to strengthen their study habits and these activities motivate and lead them to study.

On the other hand, the video is the activity most positively assessed, as non-classroom activity, by first courses' students (see question Q6 in Figure 7). The students greatly enjoy such activity, because it motivates them to express themselves, to understand the concept, to develop new ideas in a topic, etc.

Moreover, we think that this activity is really helpful nowadays, since students search educational videos to clarify key concepts in the Internet. These videos clarify them how to install software, how to work with a specific IDE, or how to solve a mathematical equation, etc. The most popular free video-sharing website for user-created content is YouTube (Lee & Lehto, 2013), but it is only an example.

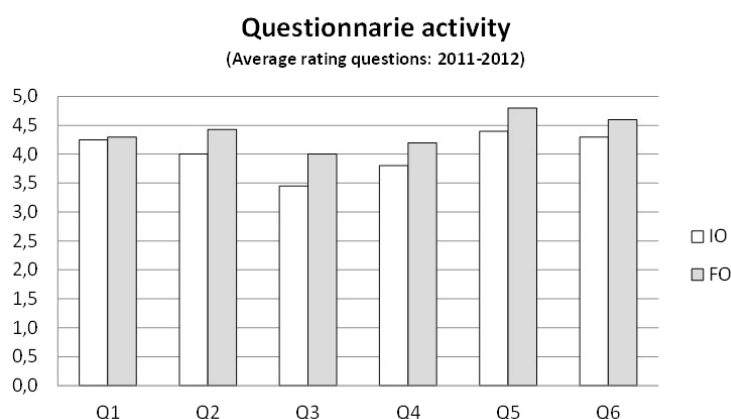


Figure 5. Mean rating for statements Q1-Q6 in Table 6 to the questionnaire activity

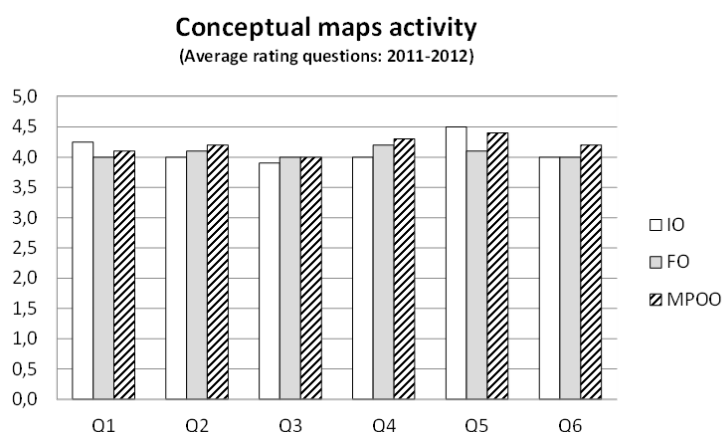


Figure 6. Mean rating for statements Q1-Q6 in Table 6 to the conceptual maps activity

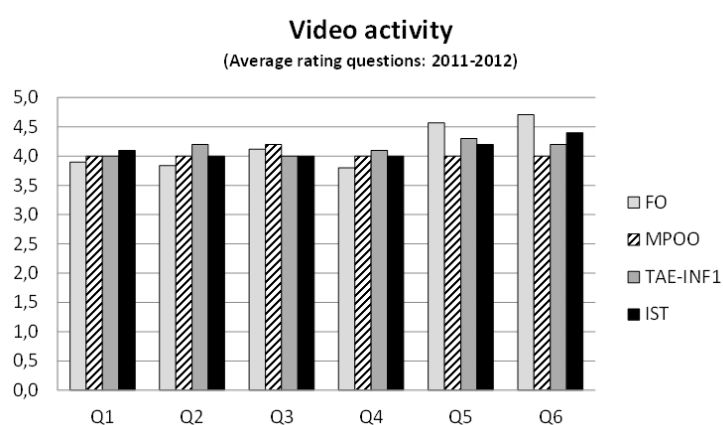


Figure 7. Mean rating for statements Q1-Q6 in Table 6 to the video activity

Finally, we think that if the video activity is done in the first years of a degree and it is intensified in the following years, the oral communication skill and the quality of the presentations of the students improve more than if it is not promoted.

Figures 8 and 9 show that the jigsaw and project activities have maximum assessment for the question Q2 (With this activity, I've significantly progressed in the achievement of generic skills defined in this course), which demonstrates that both activities helped in the development of the associated generic skills, which are autonomous learning and work in group. The assessment increases to the extent that activities are repeated in final years, obtaining the maximum assessment in the IST subject. This is due to IST is a subject of the last year where students feel that they are ready to work in group and learn autonomously, as well as to develop other skills like problem solving and team management.

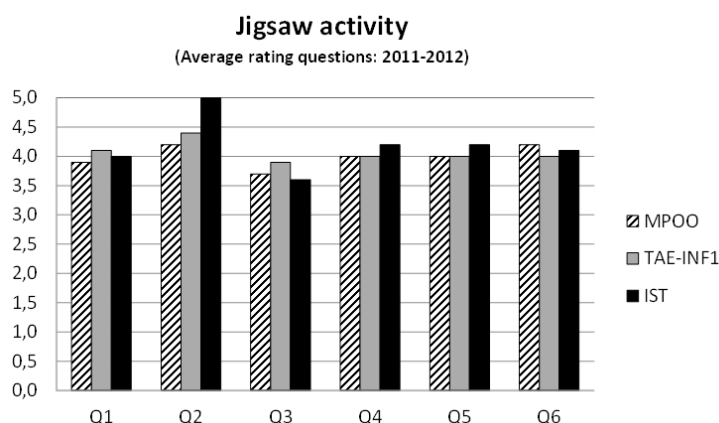


Figure 8. Mean rating for statements Q1-Q6 in Table 6 to the jigsaw activity

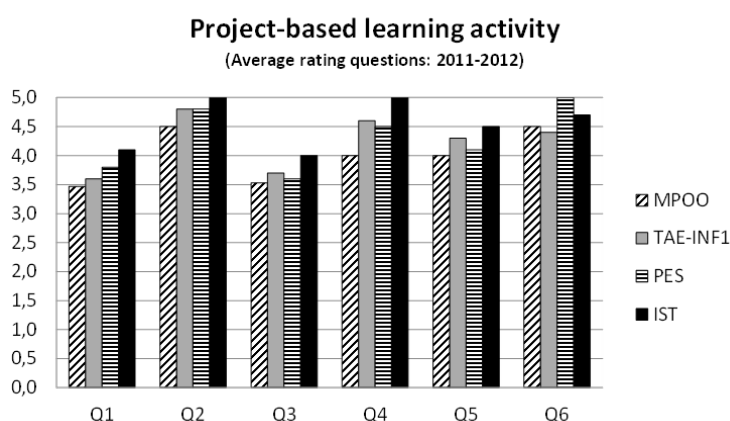


Figure 9. Mean rating for statements Q1-Q6 in Table 6 to the project-based learning activity

The project activity is in general highly valued, in subjects of the first years where small groups of students work together in a guided project, as well as in subjects of the last years where bigger groups of students work together in ambitious projects. The assessment of this activity stands out for the IST subject, since the project addresses real problems or products that motivate the students. The project activity leads students to improve work in group and management skills, as well as to progress in the subject learning process.

Although it has not been considered in questionnaires, students state that the activity that requires more effort is the project. Furthermore, just as the activity is done in higher years, students devote more time, probably because projects are more ambitious. This information is extracted from the achievements template (see Figure 4). In the projects developed in the other subjects, we have a similar situation. This is one of the points that we have to improve, reconsidering the scope of the projects. Nevertheless, students' satisfaction increases when projects require more effort. This contradiction owes probably to the fact that projects in last years' subjects can be designed for students with a major knowledge level, which implies that they can be competitive with counterpart projects in real markets, increasing the interest and motivation of students.

Finally, we don't include in this work the assessment of subjects for different years; but we can state that it improves to the extent that different editions of the activity are done in following semesters. Teachers improve the development of the activities according to the feedback given by the students, as well as the weak points detected during the semester.

6 CONCLUSIONS

This paper has proposed five activities to encourage self-learning in bachelor degrees. It proposes how to develop them in different engineering courses, emphasizing the different methodologies used depending on the area of knowledge of the subject and the cognitive complexity level (from basic to higher). Activities in first year courses are more guided, supervised, conducted in small groups and less ambitious than in last years, where students strengthen management, conflicts resolution and communication skills.

For the activities a rubric is proposed to assess them. Rubrics also vary depending on the subjects' cognitive complexity level and associated generic skills.

Finally, this paper presented an analysis of the students' satisfaction for each activity. It is worth noting that the activities that most contribute to contents' learning process are conceptual maps and questionnaires. Video is the activity most positively assessed as non-classroom activity; while, jigsaw and project activities are highly valued for the development of generic skills. Additionally, students' satisfaction increases to the extent that the activity is familiar for them. In the same way, skills assessment improves when are developed in different subjects. One example is the work in group skill, which highly improves in the last years, when students already acquired habits of work and their relation with teammates has improved.

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