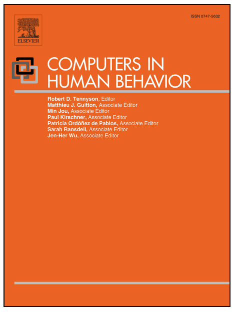
Accepted Manuscript



Developing a videogame for learning signal processing and project management using project-oriented learning in ICT engineering degrees

Ignasi Iriondo, José A. Montero, Xavier Sevillano, Joan C. Socoró

PII: S0747-5632(19)30111-6

DOI: https://doi.org/10.1016/j.chb.2019.03.019

Reference: CHB 5955

To appear in: *Computers in Human Behavior*

Received Date: 27 April 2018

Revised Date: 21 December 2018

Accepted Date: 17 March 2019

Developing a videogame for learning signal processing and project management using project-oriented learning in ICT engineering degrees

[Corresponding Author]

Ignasi Iriondo
ignasi.iriondo@salle.url.edu
GRETEL - Grup de Recerca en Technology Enhanced Learning
La Salle - Universitat Ramon Llull
C/ Quatre Camins, 30
ZIP code: 08022, Barcelona, Spain.

Phone number: (+34) 93 290 24 52
Fax number: (+34) 93 290 23 85

José A. Montero
joseantonio.montero@salle.url.edu
GRETEL - Grup de Recerca en Technology Enhanced Learning
La Salle - Universitat Ramon Llull
C/ Quatre Camins, 30
ZIP code: 08022, Barcelona, Spain.

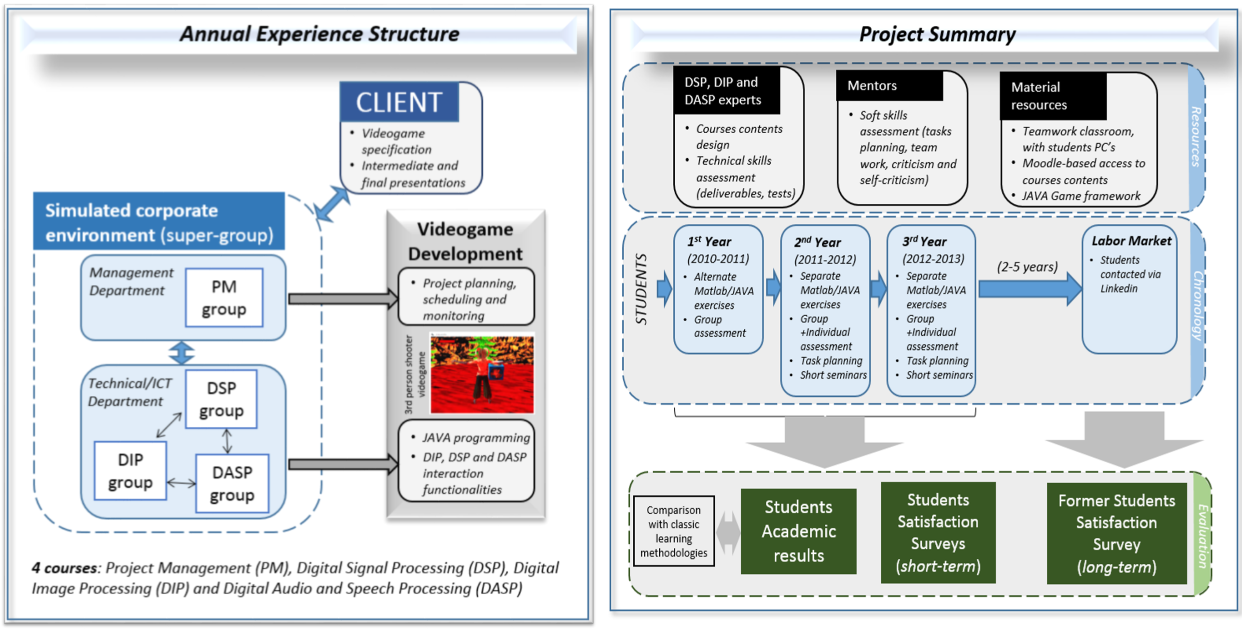
Xavier Sevillano
xavier.sevillano@salle.url.edu
GTM - Grup de Recerca en Tecnologies Mèdia
La Salle - Universitat Ramon Llull
C/ Quatre Camins, 30
ZIP code: 08022, Barcelona, Spain.

Joan C. Socoró
joanclaudi.socoro@salle.url.edu
GTM - Grup de Recerca en Tecnologies Mèdia
La Salle - Universitat Ramon Llull
C/ Quatre Camins, 30
ZIP code: 08022, Barcelona, Spain.

ABSTRACT

This work describes the design, implementation and evaluation of a multi-subject learning experience based on the principles of Constructionism, in which the construction of a videogame is the learning artifact that engages students in four different technical and management subjects included in the ICT engineering degree curricula of the School of Engineering at La Salle – Universitat Ramon Lull. Working in groups in a simulated corporate scenario, students learnt the basics of emergent technologies such as 3D audio, computer vision or speech recognition, while developing soft skills like negotiation or work planning. As regards the evaluation of the academic results, the proposed methodology made attendance rate rise from around 50% to over 90%, and average pass rate from 72% to 93%. Moreover, to capture their short and long-term view of the learning experience, students answered two opinion surveys along time: the first on completion of the project, and a second one 3 to 5 years after completing their graduate studies, with all of them integrated in the labor market. The analysis of these surveys reveals that over 85% of students showed a high degree of satisfaction, and an overwhelming preference for the new methodology over classic learning methodologies.

Keywords: Constructionism; Project-oriented learning; Active learning; Soft skills; Engineering skills; Multidisciplinary teamwork



Annual Experience Structure
CLIENT
Videogame specification
Intermediate and final presentations
Simulated corporate environment (super-group)
Management Department
PM group
Technical/ICT Department
DSP group
DIP group
DASP group
Videogame Development
Project planning, scheduling and monitoring
3rd person shooter videogame
JAVA programming
DIP, DSP and DASP interaction
functionalities
4 courses: Project Management (PM), Digital Signal Processing (DSP), Digital Image Processing (DIP) and Digital Audio and Speech Processing (DASP)
Project Summary
DSP, DIP and DASP experts
Courses contents design
Technical skills assessment (deliverables, tests)
Mentors
Soft skills assessment (tasks planning, team work, criticism and self-criticism)
Material resources
Teamwork classroom, with students PC's
Moodle-based access to courses contents
JAVA Game framework
Resources
STUDENTS
1st Year (2010-2011)
Alternate Matlab/JAVA exercises
Group assessment
2nd Year (2011-2012)
Separate Matlab/JAVA exercises
Group +Individual assessment
Task planning
Short seminars
3rd Year (2012-2013)
Separate Matlab/JAVA exercises
Group +Individual assessment
Task planning
Short seminars
(2-5 years)
Labor Market
Students contacted via Linkedin
Chronology
Comparison with classic learning methodologies
Students Academic results
Students Satisfaction Surveys (short-term)
Former Students Satisfaction Survey (long-term)
Evaluation

Developing a videogame for learning signal processing and project management using project-oriented learning in ICT engineering degrees

Abstract

This work describes the design, implementation and evaluation of a multi-subject learning experience based on the principles of Constructionism, in which the construction of a videogame is the learning artifact that engages students in four different technical and management subjects included in the ICT engineering degree curricula of the School of Engineering at La Salle – Universitat Ramon Lull. Working in groups in a simulated corporate scenario, students learnt the basics of emergent technologies such as 3D audio, computer vision or speech recognition, while developing soft skills like negotiation or work planning. As regards the evaluation of the academic results, the proposed methodology made attendance rate rise from around 50% to over 90%, and average pass rate from 72% to 93%. Moreover, to capture their short and long-term view of the learning experience, students answered two opinion surveys along time: the first on completion of the project, and a second one 3 to 5 years after completing their graduate studies, with all of them integrated in the labor market. The analysis of these surveys reveals that over 85% of students showed a high degree of satisfaction, and an overwhelming preference for the new methodology over classic learning methodologies.

Keywords: Constructionism; Project-oriented learning; Active learning; Soft skills; Engineering skills; Multidisciplinary teamwork

1. Introduction

The scope of the scientific and technical skills that must be acquired in engineering degrees' curricula is one of the greatest challenges students face during their studies. In fact, students must not only understand the theoretical foundations of several disciplines, but they must also develop problem solving skills to put this theoretical knowledge into practice. This challenges their ability to design and implement feasible solutions, as well as their capacity to detect and correct mistakes, evaluate and criticize their own work.

For this reason, many subjects in engineering degrees have traditionally consisted of theoretical and practical work. However, these two facets have often been treated as separate entities within a single subject. This inevitably leads to a disconnected view of theory and practice, which makes it difficult for students to consolidate their knowledge to tackle and solve challenging multidisciplinary problems (Felder, Woods, Stice, & Rugarcia, 2000).

During its 50+ years of existence, the learning methodologies employed at the School of Engineering in La Salle – Universitat Ramon Lull (SALLE-URL) have prioritized the practical side of student learning, ensuring that our graduates are qualified for their seamless integration in the labor market. However, our context is not immune to the effects of the widespread and ubiquitous presence of new technologies in nearly every aspect of society. Not only are students used to learning via technology-enriched methodologies in pre-university studies (which makes it difficult for teachers to ensure their engagement during the learning process if it is based on oral lectures), but also that the rapid changes in technology are reshaping the skills corporations expect from the engineers of the future. In the new professional world, it is no longer what an engineer knows, but how they and are able to apply what they learn (Kamp, 2013).

Allowing for the convergence of these two situations, the School of Engineering at SALLE-URL permanently reviews and updates the learning methodologies employed in its ICT engineering degrees. In this ongoing revision context, constructionism provides a set of ideas and tools that enable faculty to improve learning processes by increasing student engagement, consolidating knowledge by interweaving theory and practice, and endow students with new abilities which are highly sought after in the corporate environment.

In this context, this work describes the design, implementation and evaluation of a new experience that goes beyond the application of the Project-Oriented Learning methodology to a specific subject in a single engineering degree. In particular, this experience involved 3rd and 4th year students of different degrees enrolled in signal processing and project management subjects.

On one hand, the signal processing related subjects involved in this multi-subject experience are designed to allow students acquire the necessary skills required to process speech, images and sound. These skills are applicable in emerging technology fields like virtual reality, computer vision, or natural human-computer interaction, to name a few. On the other hand, the project management subject allowed the students to learn about how to plan, monitor and implement correction measures on the development of a project.

In a nutshell, the whole experience was based on the implementation of a videogame, which served as the learning artifact, in a simulated corporate environment. In this context, the students of the signal processing related subjects had to develop new interaction functionalities for the videogame, while the project management students were in charge of managing the project development. Moreover, students worked in groups, which enabled students to develop soft skills besides the technical skills, both of which were necessary for the success of the project.

To evaluate the results of this experience, we present an analysis of the academic outcome (i.e. grades) and opinion surveys conducted among the participating students. Moreover, to provide a long-term analysis, we also surveyed the same students several years after their participation in the experience. In most cases, the students surveyed in this second stage were already integrated in the labor market, so it was interesting to know whether the experience had provided them with useful skills in their professional lives.

Thus, the main contributions of this work are related to different aspects of the design of the learning experience, together with its implementation and evaluation.

With respect to the design, firstly, we want to highlight the scope of the designed experience, in which students from different ICT engineering degrees, subjects and academic years worked together. Secondly, this Project-Oriented Learning multi-subject experience pivoted around the construction of a videogame artifact in a simulated corporate environment. And finally, the teaching staff was separated into the roles of experts and mentors, which allowed a specialized evaluation of the technical and soft skills acquired by the students.

In regard to the implementation of the experience, one of the main contributions of this work is that students were grouped into multidisciplinary groups following predefined criteria that allowed to ensure intergroup balance between practical and theoretical skills.

And finally, the evaluation of the experience also presents an important novelty, since in addition to comparing the academic results obtained (before and during the implementation of the experience), we conducted short- and long-term opinion surveys to students. This allow us to extract some meaningful conclusions about the usefulness of the skills learned once they have entered the labor market.

The manuscript is organized as follows: Section 2 presents the pedagogical framework and describes the specific contributions of this work. Section 3 describes the design process of the experience, including the artifact pre-design, the profiles of the teaching staff involved, the planning of the tasks composing the project and the student evaluation protocol. Section 4 presents the case study consisting in the development of the experience over three consecutive academic years. Section 5 presents the evaluation results, while Section 6 discusses the conclusions of this work and outlines further work.

2. Fundamentals and background

2.1. Theoretical background

According to the most relevant pedagogical theories of the last century, the role of the student in the learning process has suffered great changes over time. At the beginning of the 20th century, Behaviorism deemed students as an empty container to be filled with knowledge that was directly transmitted by the instructor. Thus, learning was an information accumulation process that allowed to acquire a set of isolated skills. In the second half of the 20th century, Cognitivism, and later, Constructivism, introduced a paradigm shift by posing the idea that students were active agents in the learning process, using experimentation and their previous knowledge to build new knowledge (Steffe & Gale, 1995). In this sense, Piaget stated that knowledge is the experience acquired through the interaction with the world (Ackermann, 2001; Harel & Papert, 1991). Nowadays, in the so-called Digital Age, the Constructionism led by Seymour Papert emphasizes on the idea that knowledge is built from the students’ action. In this sense, Papert focuses on the art of “learning to learn”, and highlights the importance of the construction of learning artifacts by students (Ackermann, 2001), underlining the importance of a context in which students feel consciously engaged.

The principles of Constructionism can be implemented by means of several methodologies, such as Problem Based Learning (PBL) (Hung, 2016), Project Oriented Learning (POL) (DeFillippi, 2001) or Case Based Learning (CBL) (Rosenstand, 2012), which foster the acquisition of knowledge via experimentation and discovery. Among them, POL is particularly suitable for implementing the principles of Constructionism, as it makes the student experiment and learn within a context designed by the instructor, with the ultimate goal of constructing a learning artifact.

In recent years, pedagogical models in higher education have also shifted from traditional behaviorist models (with oral lectures at the core of the learning process) to constructionist models based on the student-centered idea of “learning by doing”, in which students take a more active role, and cooperative learning becomes especially relevant.

Focusing on the education of future engineers, society needs professionals with both excellent technical and soft skills, who are capable of working in multidisciplinary scenarios. For this reason, the application of learning methodologies that integrate different disciplines and promote teamwork is key to achieving this aim. In this sense, POL stands out as one of the most interesting methodologies available, as it allows engineering students to acquire technical knowledge at the same time as they develop the key skills and competences required to become highly competent professionals, such as the ability to work in a team, conflict management leadership, planning, or negotiation, to name a few.

There are plenty of works in the literature demonstrating that the correct application of POL outperforms traditional methodologies both in terms of academic results and student satisfaction levels. (Balemen & Keskin, 2018) provide a detailed analysis of up to 48 POL-based experiences in different types of studies, concluding that the application of POL outperforms standard learning methodologies in terms of efficiency. Focusing on engineering studies, (Mills & Treagust, 2003) advocate for the application of POL, presenting how several universities have introduced this methodology in their engineering degrees.

As mentioned earlier, this paper describes and evaluates a multi-subject learning experience that involves students of four subjects included in the ICT engineering degree curricula, in which students worked in groups in a simulated corporate scenario. In this context, and to highlight the contributions of this work, it is necessary to compare our proposal to the state of the art in the light of four crucial aspects of the design and evaluation of a POL-based educational experience:

(i) the inclusion of different subjects to emulate the multidisciplinary nature of real-life projects: most POL-based experiences reported in the literature are single-subject, with few exceptions like (Arias, Barba-Sanchez, Carrion, & Casado, 2018; Caldeira, Morais, Mesquita, & Lima, 2017). In our work, students enrolled in up to four technical and managerial subjects are involved in the same learning experience (see Section 2.2 for details).

(ii) the criteria applied to the formation of workgroups: some researchers have highlighted the fact that workgroups should be formed using criteria that maximize the efficiency of the experience (Bell & Hernandez, 2017; Maznevski, 1994). However, this aspect is often neglected (or at least not reported) in the literature, with few exceptions (like (McLoone, Lawlor, & Meehan, 2016), in which groups are formed following academic performance heterogeneity criteria). In our work, workgroups are formed using criteria that seek maximizing the experience performance (see Sections 3.1 and 4.3 for further details).

(iii) the development and evaluation of soft skills: some works, like (Amiel, Abboud, & Trocan, 2014), attempt to evaluate workgroup performance through the cross-evaluations of the students. In (Herrera, 2017), despite soft skills are not explicitly evaluated, the author discusses how POL increases the self-criticism of students, as it helps narrowing the gap between their self-evaluations and the evaluations made by the teaching staff. Several works provide soft skills evaluation based on the observations made by the subject instructor, who is also usually responsible for the development and evaluation of technical skills (Haskins, Stock, Gladysz, & Urgo, 2018; Martinez-Rodrigo, Herrero-De Lucas, De Pablo, & Rey-Boue, 2017; McLoone et al., 2016; Noguez & Espinosa, 2004; Ribu & Tulpesh, 2018). The difficulties posed by having a single instructor in charge of both types of skills are highlighted in (Noguez & Espinosa, 2004), which concludes that a figure solely devoted to soft skills development and evaluation is required in this type of experiences. Moreover, (Badets, 2017) discusses that this figure should be specifically trained to develop and evaluate the students' soft skills. In our work, this issue is tackled by assigning specific human resources to the development and evaluation of technical and soft skills, through the dual figure of experts and mentors (see Section 3.4 for a description).

(iv) surveying the students’ opinion is of paramount importance: indeed, students are often asked to complete opinion surveys right after finishing the educational experience, like in (Arias et al., 2018; Calvo, Cabanes, Quesada, & Barambones, 2018; Haskins et al., 2018; Martinez-Rodrigo et al., 2017; McLoone et al., 2016; Noguez & Espinosa, 2004). Indeed, this is instrumental to improve the educational experience and re-adjust the dedicated resources if needed. However, these surveys only provide a short-term snapshot of their view. For this reason, this work introduces the novelty of surveying the students years after completing their engineering degrees, when they are already integrated in the labor market. Thus, this second survey aims at capturing the students’ long-term view on the experience at a point in time when their professional background allows them to analyze under a different light the usefulness of the POL-based educational experience (see Section 5.2). This two-fold surveying strategy allows us to compare the results of the short- and long-term opinion surveys, providing insightful conclusions regarding the designed experience.

2.2. Background of the experience

This work presents and describes a POL multi-subject experience developed at the School of Engineering at SALLE-URL over three academic years. The experience involved students from three engineering degrees (Multimedia, Telecommunications and Audiovisual Systems) enrolled in four 3rd and 4th year subjects: Digital Signal Processing (DSP), Digital Audio and Speech Processing (DASP), Digital Image Processing (DIP) and Project Management (PM).

Until the 2009-2010 academic year, the technical subjects (DSP, DASP and DIP) had been taught following a methodology based on oral lectures and practical computer-based assignments, and evaluation mainly based on written exams. At that time, the students showed little interest in the DSP subject (which has a strong mathematical focus), with attendance to oral lectures below 50%, which consequently resulted in a low pass rate. As for the DASP and DIP subjects, pass rates were higher. However, during the years previous to this experience, the students had expressed via satisfaction surveys that they enjoyed and learned most thanks to the practical part of these subjects. Thus, it was it was clear that a stronger practical approach would increase the interest of students. Although all these subjects had practical assignments, these had a low impact in terms of evaluation.

Taking all this in consideration and in an aim to achieve a better theory-practice balance, we designed and implemented a multi-subject experience based on POL that applied the basic principles of Constructionism, so that students built their own knowledge by constructing an artifact that required the acquisition of theoretical concepts as well as the development of practical skills. In particular, the learning artifact around which the whole experience was based was a videogame.

The whole experience was designed with two main sets of goals in mind: i) specific goals related to the technical skills particular to each subject, and ii) cross-curricular goals which complemented the technical skills.

As for the former, the following goals were identified:

- The solid acquisition of the fundamental concepts of each course.
- A more practical view of signal, image, audio and speech processing to make students aware of the importance of these topics in the field of ICT engineering.

As for the latter, the following cross-curricular goals were identified:

- Improve students' ability to work in groups.
- Improve students' ability to plan tasks.
- Acquire other highly sought-after soft skills.

To increase student motivation and engagement, the whole experience was designed within a simulated corporate environment. To that end, the students enrolled in the Project Management (PM) subject also took part in the experience, and their role was to manage the technological project developed by their colleagues of the DSP, DASP and DIP subjects.

The following sections describe the design, implementation and evaluation of the experience over three consecutive academic years.

3. Design of the experience

As mentioned earlier, the experience consisted in engaging students in a simulated corporate environment, with the ultimate goal of creating a videogame that requires students to put into practice the concepts related to four subjects of three engineering degrees: DSP, DASP, DIP and PM. This section describes the design of the whole experience.

3.1. Simulation of a corporate environment

The students played the role of staff members of a technological development company developing a project for a fictitious client.

The client was a publishing house that wanted to promote a collection of books for teenagers, called "Land of Dragons". As a part of the marketing campaign to reach their young audience, the client had the idea of placing videogame booths in bookstores. The videogame had to feature one of the "Land of Dragons" characters and include advanced interaction technologies to engage potential book buyers.

From an organizational standpoint, students were grouped in *supergroups* and *groups*. Each supergroup comprised four groups, each one of which was formed by students of one of the four subjects. The number of students per group ranged between 4 and 6 (see Figure 1).

In each supergroup, the students of the DSP, DASP and DIP subjects played the role of members of the technical department of the company. On the other hand, the PM students played the role of project managers, and their mission was to manage the project of development of the videogame within the aforementioned simulated corporate environment.

To make the simulation more realistic, the students held a meeting with the client (role played by a faculty member unrelated to any of the four participating subjects) at the beginning of the course in which the client outlined his or her product specifications and requirements of the videogame (see Figure 1). At the end of the academic year, each supergroup made a presentation to the client highlighting the main characteristics of the developed product.

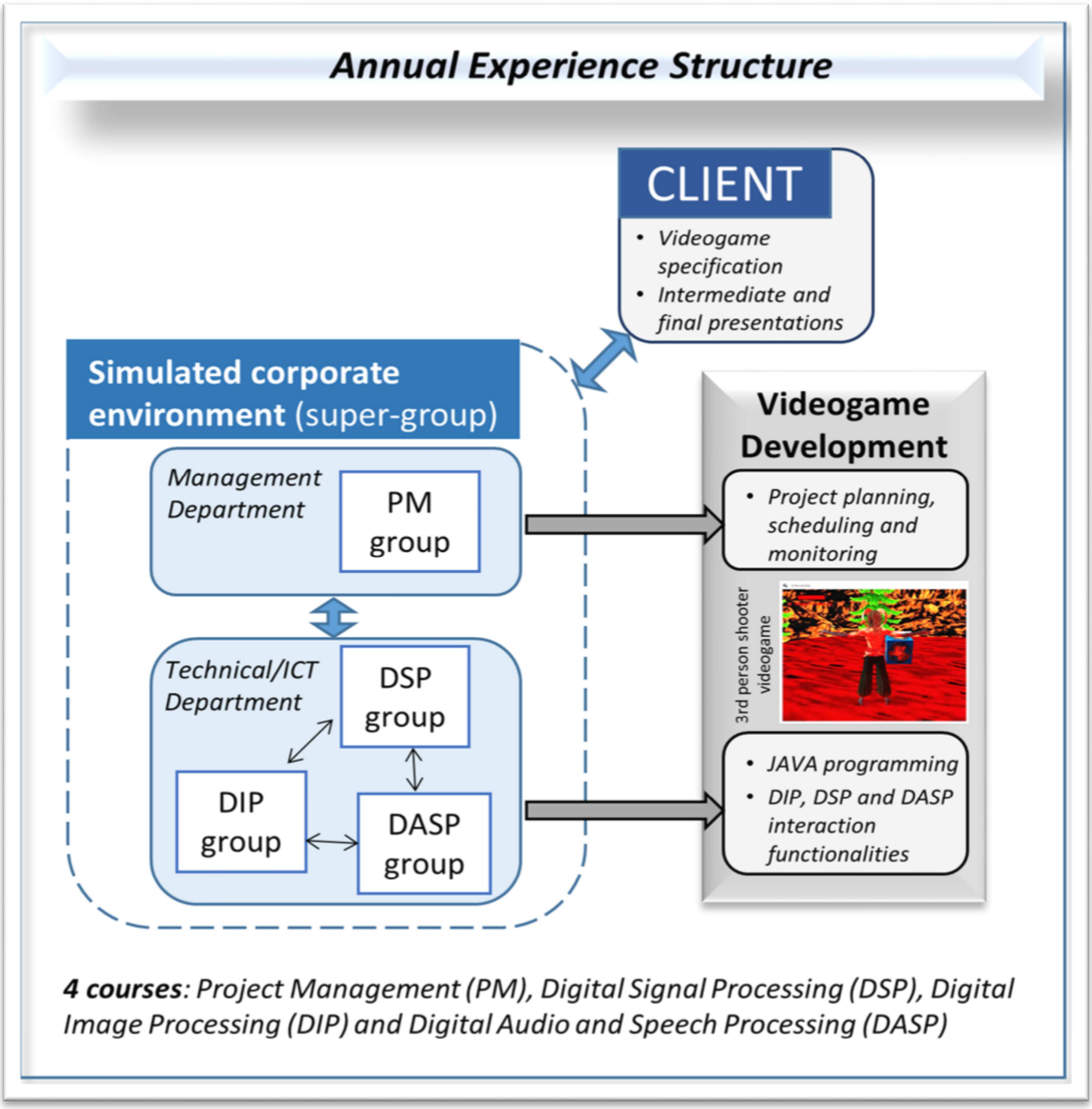


Figure 1. Structure of the multi-subject POL-based learning ex-based learning experience during one academic year.

3.2. Artifact description

As mentioned earlier, the learning artifact to be developed by the students was a videogame. At the beginning of the course, the students were provided with a basic videogame framework written in Java, consisting in a third-person shooter videogame, in which the avatar movements and actions were initially controlled via keyboard (see Figure 2).

The students of the three technical subjects (DSP, DASP and DIP) had to put into practice many of the concepts related to each technical subject to incorporate multimedia user interaction functionalities into videogame, in particular i) deactivation of acoustic mines by means of filtering (DSP), ii) speech-based avatar control and 3D audio (DASP), and iii) configuration of the game scenario via object recognition in images (DIP).

To illustrate this, Figure 2a shows the schematic image on which DIP students had to recognize different types of objects (trees, walls, rocks and pyramids) that would then be placed on the real videogame scenario (see Figure 2b). On the other hand, DSP students had to implement filtering techniques to eliminate acoustic mines that emitted annoying sounds of specific frequencies, as shown by the spectral graph appearing at the bottom right corner of Figure 2c. And finally, DASP students had to implement recognition techniques for specific spoken commands to move the character around the game scenario and order him to shoot against the enemies, plus 3D audio algorithms to find the position of the enemies.

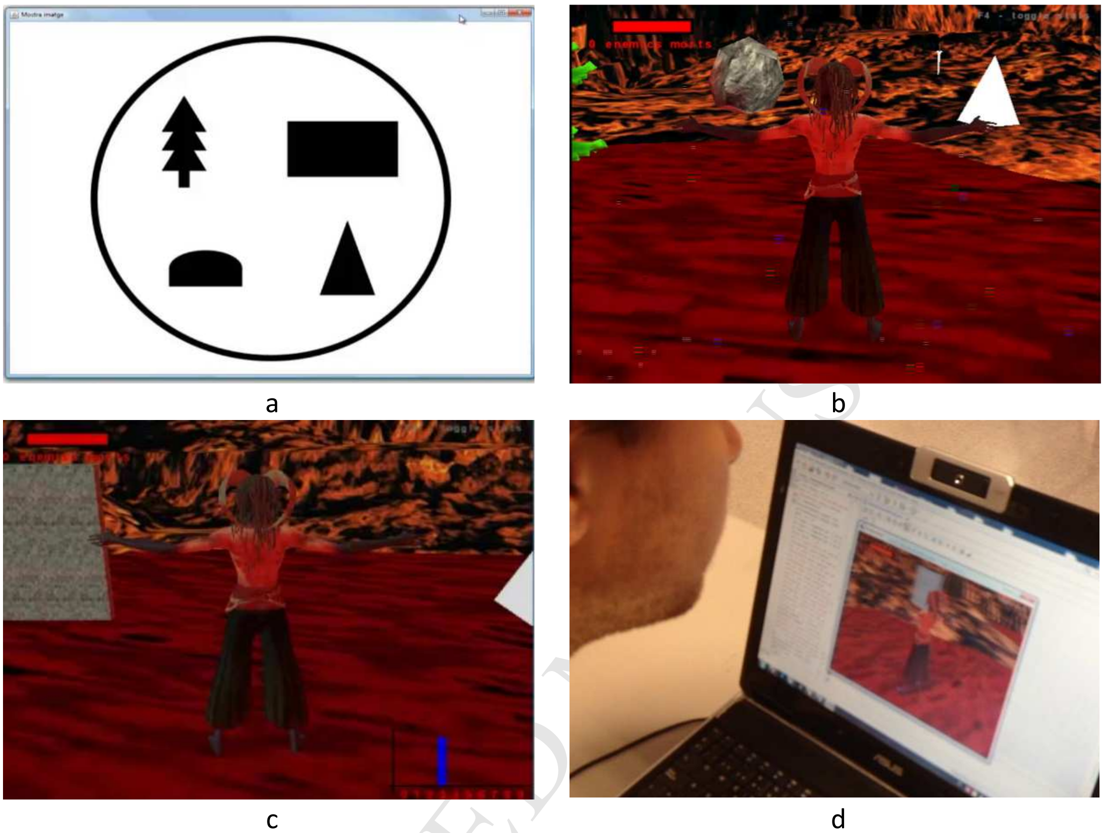


Figure 2. Videogame screenshots

On the other hand, the PM students had the chance to put into practice the concepts related to project planning and scheduling and had to hold regular meetings with their colleagues of the technical subjects to monitor the progress of the project.

3.3. Course planning and design

To emulate the development of a real project in a corporate environment, the course was planned as a sequence of eight phases, each of which had a set of tasks to be submitted (see Figure 3). The whole course was designed to last 26 weeks.

During the proposal, conceptual design and in-depth design phases, the students attended a series of lectures that equipped them with the specific technical and managerial skills required to undertake the prototype and product development phases.

For the students, the work unit was the task. The number of tasks depended on the specific subject, and some tasks (like prototype integration or quality control) were common to all the technical subjects. Once a task had been completed, the contents of the next one were made available to the students. It is important to note that, besides the tasks for each subject (i.e. designed to let students gain the skills related to the DSP, DASP, DIP or PM courses), there were tasks specifically designed to foment interaction between the project managers and the technical team members of the same supergroup (for instance, the project progress monitoring meetings).

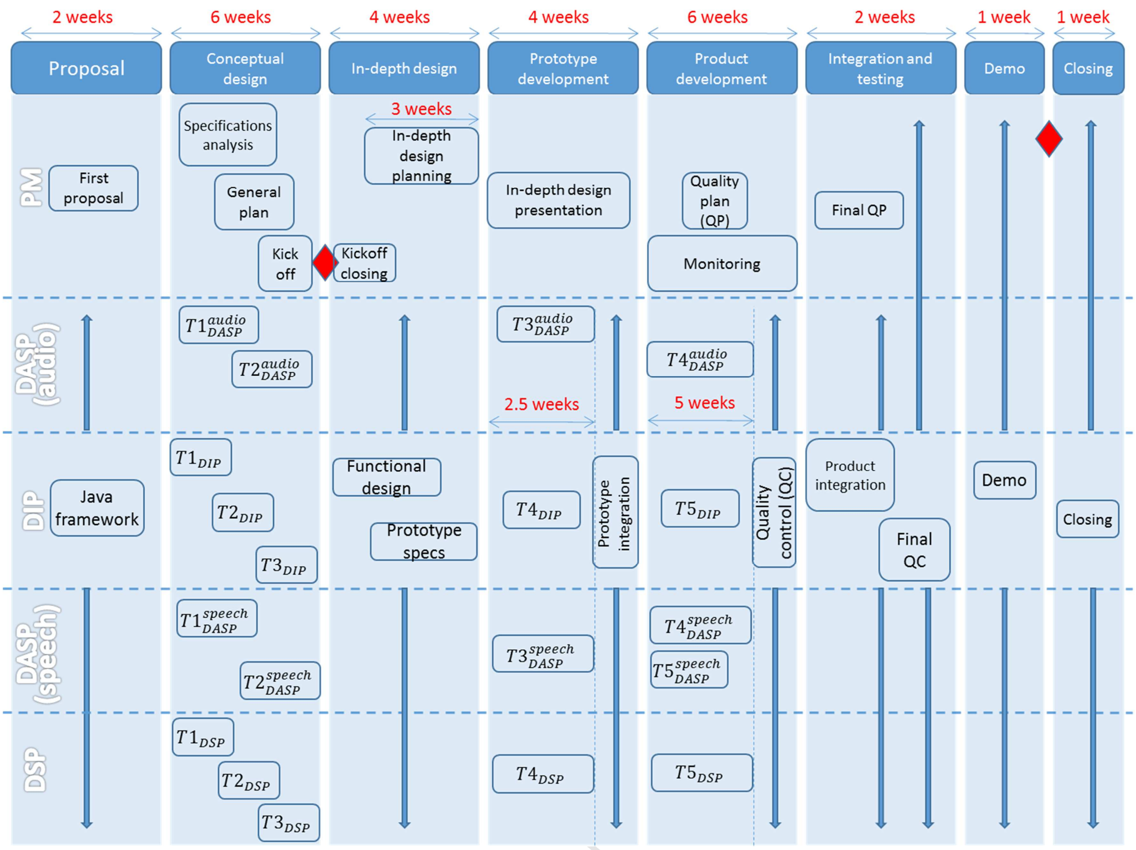


Figure 3. Course planning in phases and tasks

3.4. Experts and mentors

The teaching staff involved in the design, development and monitoring of the course were divided into experts and mentors. On one hand, the experts were in charge of developing the contents of the four subjects (DSP, DASP, DIP and PM), as well as of solving technical doubts or discuss specific issues regarding the subject documentation and the assigned tasks during the weekly workgroup sessions. On the other hand, mentors were responsible for tracking the dynamics within each group and supergroup, detecting areas of conflict and helping the students to solve them. To that end, mentors held weekly meetings with the groups in order to assess their progress at both organizational and planning levels, helping groups through the different stages of group dynamics that naturally occurred over the length of the experience (aiding them to deal with situations involving frustration, conflict and confusion).

Thus, the experts could be regarded as responsible for ensuring that students acquired the skills specific to each of the four subjects, while mentors could be deemed as being in charge of helping students gain soft skills such as negotiation, interpersonal conflict management, task planning, and so on. To that end, both experts and mentors held at least one meeting with the groups during the weekly workgroup sessions.

Moreover, experts and mentors were in charge of preparing a corpus of documentation for both the students and the teaching staff.

As regards the documentation made available to the students, experts designed the documents describing each task, including the theoretical contents required to solve them while the mentors prepared a series of documents such as templates for the weekly planning of tasks, peer-to-peer evaluation rules, or templates for personal reflections.

As regards the documentation available only to the teaching staff, experts prepared the so-called "experts guide". This document aimed to serve as a guide for any teacher who joins the project or who wants to apply this teaching methodology in another subject. Thus, it details how to implement the project (teaching staff roles, course dynamics) and also provides a detailed description of the content of the tasks in which the project is structured from the point of view of each specific subject. Similarly, mentors prepared the "mentors guide", which included information related to the dynamics to be followed during the meetings with the groups, and also aspects related to soft skills evaluation.

3.5. Evaluation methodology

One of the keys of the success of this experience is tracking how the construction of the artifact influences the learning process of the students. In this experience, students are expected not only to acquire the skills related to the technical subjects, but also to acquire soft skills during the group construction of the artifact. Experts are in charge of evaluating the former set of skills, while mentors are responsible for evaluating the latter.

Of course, it was necessary to clearly determine which skills were to be evaluated. Moreover, another key issue was that despite working in groups, each student had to be evaluated individually. Thus, evaluation strategies at both group and individual levels had to be designed.

Focusing on the technical skills evaluation, the completion of each task required each group to submit a deliverable through an online Moodle-based platform. Furthermore, each task was also evaluated by means of a two-fold validation test right after each task completion. The first part of this validation test was conducted in groups, and it consisted of adapting the code developed during the task to solve a problem that was slightly different to the one tackled during the task, so that students could prove they had understood the underpinnings of the task. Immediately after the group test, an individual test focused on the theoretical foundations of the task was conducted. Taking into account that five specific technical tasks were completed in each subject (see Figure 3), a total of five group and individual tests were conducted per subject. As a result, each student was doubly graded after each task, i.e. at individual and at group levels.

As for the evaluation of the soft skills, the students had to complete a group work planning document and an individual work assignment at the beginning of each task. Moreover, as an individual exercise, the students completed i) a confidential evaluation report on the his/her group peers to complete the assigned tasks in due time and their contribution to the group functioning, and ii) a document containing personal reflections about the work completed as a group. Thanks to this, mentors were able to evaluate transversal skills such as the ability of criticism and self-criticism, team work, among others.

Finally, the mark of each student was computed by weighting the following items: i) soft skills mark (30%), ii) individual technical skills mark (50%), and iii) group technical skills mark (20%).

4. Case study: implementation during three academic years

This section describes the main aspects of the implementation of the experience during three academic years.

To help the reader understand the chronological evolution of the experience, Figure 4 summarizes the project in terms of the required material and human resources, as well as the changes introduced in the students' evaluation activities and the experience evaluation items collected along time.

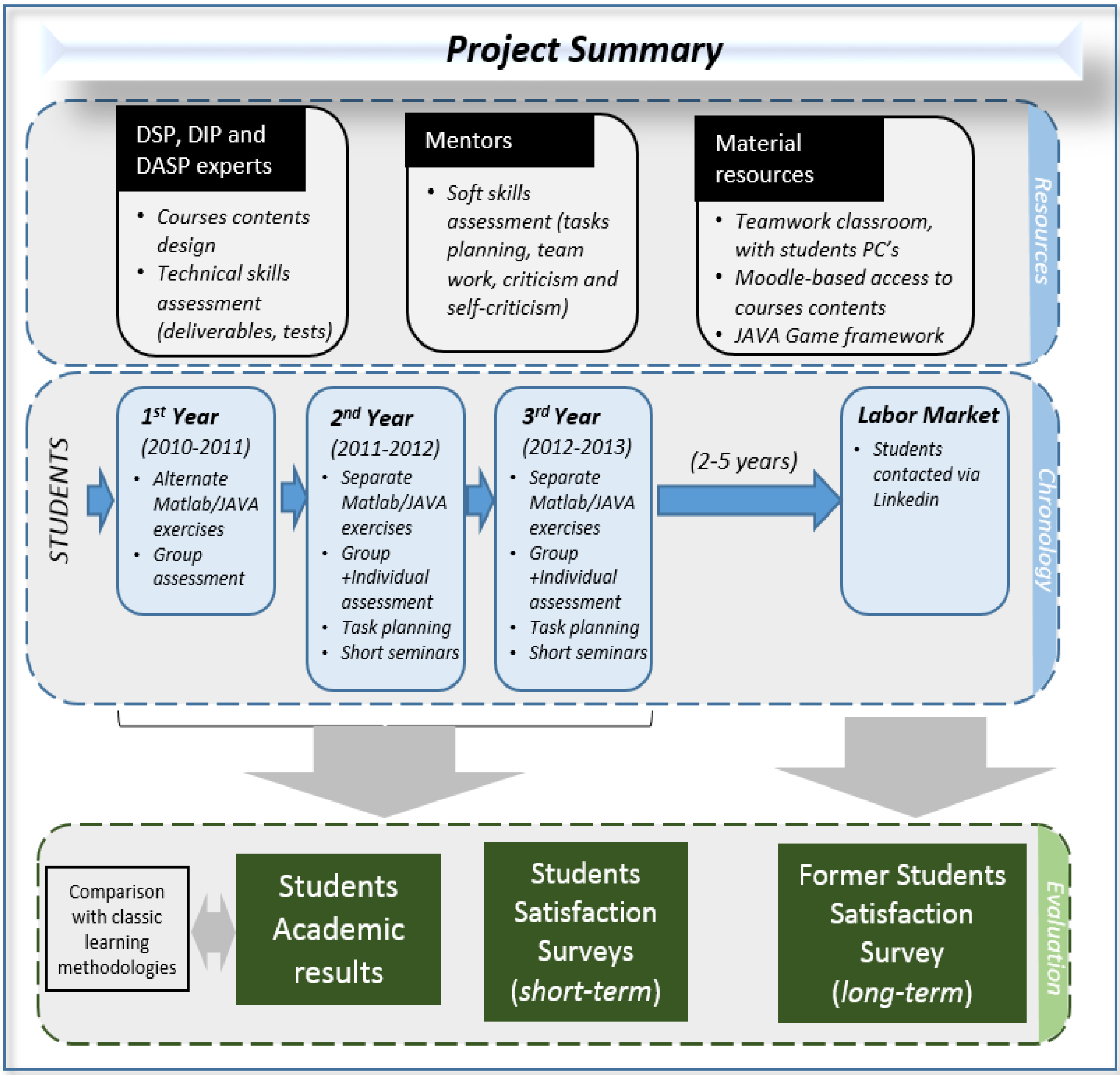


Figure 4. Project summary at a glance.

4.1. Initial presentation

At the beginning of each academic year, the students enrolled in the DSP, DASP, DIP and PM subjects were called to a kick-off meeting in which the main principles of the methodology were presented, including a description of the expected learning results. Furthermore, a set of documents were made available to the students, including:

- The role of the student in POL (i.e. set of attitudes and tasks at both individual and group levels that are advisable to promote a good learning experience).
- The procedures for task results submission at both individual and group level and their structure.
- The grading and evaluation procedures, highlighting the balance between soft and technical skills both at individual and group level.
- A conceptual map to provide an integrated vision of the whole experience.

4.2. Resources

This multi-course POL-based learning experience required an important set of both human and technical resources for its implementation.

As far as the human resources are concerned, two mentors and six experts (signal, image, speech and audio and two more for PM) supervised the groups and helped them during the weekly workgroup sessions during the first academic year. In the successive years, another DSP expert was added due to the increase in the number of students enrolled in this subject. Finally, the mentoring task was undertaken by more teachers to reduce the individual workload of this task.

	2010-2011	2011-2012	2012-2013
DSP expert	1	2	2
DIP expert	1	1	1
DASP expert	2	2	2
PM expert	2	2	2
Mentor	2	3	4

Table 1. Number of mentors and experts involved in the experience each academic year.

As for the workload of the teaching staff involved in the experience, Table 2 presents the total workload in hours corresponding to i) the classic (i.e. lecture based) methodology used previously in the subjects, ii) the POL-based methodology during the first year, and iii) the POL-based methodology during the second and third academic years.

It can be observed that the workload during the first year of the experience more than doubled (i.e. relative increases higher than 100%) the workload corresponding to the classic methodology. This fact, coupled to the new workload derived from the inclusion of the figure of the mentor, should be taken into account when implementing this kind of experiences (especially during the first year, which requires preparing large volumes of documentation).

During the second and third years, the workload was lower, but still significantly higher than in the classic methodology.

	Classic methodology	First year	Relative increase	2nd and 3rd years	Relative increase
DSP	192	502	161%	299	56%
DIP	112	284	153%	200	79%
DASP	96	202	111%	150	56%
Mentoring	0	200	-	132	-

Table 2. Workload (in hours) of the teaching staff involved in the experience, compared to the workload of the classic methodology.

As for the students' workload, they had to attend the aforementioned mandatory weekly on-site classes lasting 2 hours and 50 minutes per subject. However, the workload of the whole experience required that they worked on the subjects out of class, although no records on the total work time were collected.

As regards the material and technical resources, the work sessions of the learning experience physically took place in a 200 square meter classroom especially conceived for teamwork, equipped with Wi-Fi and several electric sockets to allow the students work with their own laptops, and with one PC and projector screen for experts to make presentations. Other physical spaces employed during the experience were an auditorium to hold the initial meeting with the client, and a medium-sized classroom to perform supergroup presentations to the client (one supergroup at a time). As for virtual resources, the videogame Java framework was continually revised and maintained by technical staff. Moreover, a Moodle-based intranet enabled access to documentation and data, as well as surveys, among others.

4.3. Criteria for workgroup formation

As mentioned before, the way workgroups are formed plays a key role in the achievement of good learning results both in terms of technical and soft skills. In this experience, students were not given the chance to choose their group partners, and the composition of the workgroups was decided by the teaching staff at the beginning of the academic year. By doing so, we intended to replicate the situation in real life, when often it is not possible to choose who you work with.

In our case, the following set of criteria were defined at the time of forming workgroups:

- The number of students per group ranged between 4 and 6
- Each group had to encompass students from as many different engineering degrees as possible (Multimedia, Telecommunications and Audiovisual Systems)
- When possible, at least one member of the group had to be enrolled in the three technical subjects (DSP, DASP and DIP)
- At least one member of the group had to be a Multimedia engineering degree student (to guarantee good knowledge of the Java programming language)

As already described, four groups (i.e. DSP, DASP, DIP and PM groups) were organized into a supergroup. To form supergroups, a set of criteria were followed:

- Students enrolled in two or more technical subjects (i.e. belonging to two or more groups) were assigned to the same supergroup
- Students enrolled in at least one technical subject and in the PM subject had to develop their technical and project management profiles in different supergroups (thus preventing a student playing both the technical and the managerial roles in the same supergroup)

Table 3 shows the number of groups (per subject) and supergroups formed each academic year. Since the number of enrolled students differed from one subject to another, it was impossible to include all students in *complete* supergroups (that is, supergroups comprising three technical groups –DASP, DIP and DSP- plus a PM group) while keeping group size between 4 and 6 students.

Of course, the number of complete supergroups was determined by the number of groups formed in the subject with the minimum number of enrolled students (which was typically DASP). Quite obviously, in these incomplete supergroups, the videogame had to include only the functionalities that could be developed by the technical groups included in the supergroup.

Also, we found that in the subjects with the largest number of enrolled students –typically DIP and DSP- we had more technical groups than available (complete or incomplete) supergroups. In this case, the spare technical groups followed the POL-based methodology but without being included in a supergroup.

The first year, 10 complete supergroups were formed. As the number of students enrolled in DIP made for a total of 11 groups, the spare DIP group followed the methodology without an assigned supergroup. The second year, a total of 14 supergroups were formed, 8 of which were complete. In this case, three DSP groups followed the methodology without being included in a supergroup. And the third year, a total of 17 supergroups were formed (7 of them complete). One DSP group followed the methodology without an assigned supergroup.

	2010-2011	2011-2012	2012-2013
Number of Super-groups	10	14	17
Number of DSP groups	10	17	18
Number of DIP groups	11	10	11
Number of DASP groups	10	8	7
Number of PM groups	10	14	17

Table 3. Distribution of the number of groups per subject and supergroups for each academic year.

4.4. Surveys

At the end of the learning experience, all students anonymously completed a satisfaction survey (one per subject). In these surveys, students were asked to give their overall perception of the experience, and also to answer more specific questions regarding the usefulness of mentoring, or whether the methodology had contributed to improving the acquisition of the expected technical and soft skills.

4.5. Meetings between mentors and experts

During the academic year, mentors and experts held regular meetings in order to exchange information about students, discussing conflicts that arose in certain groups, or other issues that allowed to improve supervision and, in the end, enhance students' performance.

A special emphasis was placed on detecting "critical cases", i.e. students that regularly failed to meet the objectives assigned by their group colleagues and whose poor participation could negatively affect the performance of the group as a whole. In those cases, the student was separated from the group and was required to do an individual task during a one-month period. After this time, the expert evaluated if the student had acquired the required technical skills. If so, the student reintegrated with the group, so he/she enjoyed a second chance to follow the course regularly. If not, the student failed the subject.

Table 4 presents the number of critical cases per year and subject, including also those that ended up failing the subject. In general terms, it can be observed that nearly half of the critical cases could be "rescued" after the one-month individual task. In aggregated terms, the failing rates were 11.2% for DSP, 6.7% for DIP and 5.2% for DASP.

		2010-2011	2011-2012	2012-2013	TOTAL
DSP	Critical	2 (3.3%)	19 (24.1%)	15 (17.6%)	36 (16.1%)
	Failed	1 (1.7%)	16 (20.3%)	8 (9.4%)	25 (11.2%)
DIP	Critical	5 (8.3%)	2 (4.8%)	10 (20.8%)	17 (11.3%)
	Failed	3 (5.0%)	1 (2.4 %)	6 (12.5%)	10 (6.7%)
DASP	Critical	8 (22.9%)	4 (12.9%)	5 (16.7%)	17 (17.7%)
	Failed	2 (5.7%)	1 (3.2%)	2 (6.7%)	5 (5.2%)
TOTAL	Critical	15 (9,7%)	25 (16,4%)	30 (18,4%)	70 (14.9%)
	Failed	6 (3.9%)	18 (11.8%)	16 (9.8%)	40 (8.5%)

Table 4. Distribution of the number of critical students per year and subject and the number of students that finally failed the subject.

4.6. Final presentation

At the end of the academic year, a final product exhibition was organized in which all the supergroups had the chance to show their videogame to the rest of the university campus community, including also the experts and the client that participated in the experience. This way, the closing of the learning experience also simulated a real-life scenario, which provided the experience with strong doses of positive interactions after all the conducted hard work.

4.7. Methodological adjustments across the 3-year experience

Over the 3-year experience, the analysis of the surveys completed by the students at the end of each academic year provided valuable information which prompted us to introduce minor changes in the methodology. As a result, some modifications of the teaching methodology were introduced year after year in order to offer an improved learning experience, such as:

- During the first year of the experience, the assessment was mainly focused on group level, which made some students rely too heavily on their colleagues. Experts noticed also that the technical knowledge of some students did not reach the desired levels, so we decided to include individual evaluation tests in each task for the subsequent academic years.
- Initially, the technical development consisted of a series of tasks that alternated: i) Matlab-based exercises with theoretical contents, and ii) Java-based exercises focused on product prototyping. However, this structure led to some students not properly consolidating the theoretical concepts of the technical courses. For this reason, the teaching staff decided to concentrate the tasks devoted to theoretical concepts together with Matlab-based exercises during the first semester, and then perform the tasks related with Java prototyping during the second semester.
- Task planning was introduced during the second year, as a means to help student acquire organizational skills through a schedule-based planning document that was weekly updated by group participants.
- In the surveys collected during the first year, some students emphasized the need for more comprehensive resources, especially for the DSP subject, as its syllabus contains more complex theoretical concepts than the other courses. This motivated the introduction of short seminars given by the experts to all groups, which were scheduled mainly half-way through the tasks that contained relevant and complex theoretical foundations, reinforcing by this way the acquisition of key concepts and giving a complementary perspective from the rest of document-based resources. In order to not deviate from the principles of the POL methodology, those short seminars were programmed after the students had read the full documentation and the expert detected the general need of such kind of theoretical support.
- As regards the students’ performance, in the first year we detected that students which enrolled in three or four technical subjects were hardly able to cope with the whole experience workload. For this reason, from the second year we started recommending students not to enroll in more than two subjects (of the four) per academic year.

5. Results

The evaluation of this kind of learning experiences is usually conducted by means of opinion surveys among students during or at the end of the academic year. In this work, we have complemented these surveys by reaching out to our former students a few years later, once they were integrated in the labor market.

Moreover, besides the subjective opinion of students collected via surveys, we have also performed a statistical analysis of the academic results (pass rate and quit rate) obtained when this methodology was applied and when the courses were given using classic methodologies (i.e. oral lectures plus practical assignments).

It is important to state that the analyzed survey results were those corresponding solely to the students enrolled in the technical subjects (DASP, DIP and DSP), as it was for these students that the whole educational experience constituted a greater change with respect to the way those subjects were taught until that moment. For this reason, we consider that the opinions of these students are the most meaningful as regards the evaluation of the learning experience. Thus, the analysis of how the proposed methodology impacted the PM students lies beyond the scope of this work.

5.1. Students satisfaction surveys

Satisfaction surveys were conducted during the last week of the academic year over three successive years (2010-11, 2011-12 and 2012-13), collecting a total 429 surveys. As mentioned earlier, each student anonymously completed one survey per subject he/she was enrolled in.

Figure 5 shows the distribution of the number of students enrolled in one, two or three technical subjects at the same time. In total, the number of students that followed one or more of the three technical subjects (DSP, DASP and DIP) under the described POL-based experience is 258 unique students. This figure is smaller than the sum of the three annual values because some students participated in this experience in consecutive academic years enrolled in different subjects. Similarly, the total number of enrollments is greater than the number of students participating in this experience during the three academic years analyzed, as many students enrolled in different subjects. This amounts to 470 enrollments throughout the three academic years.

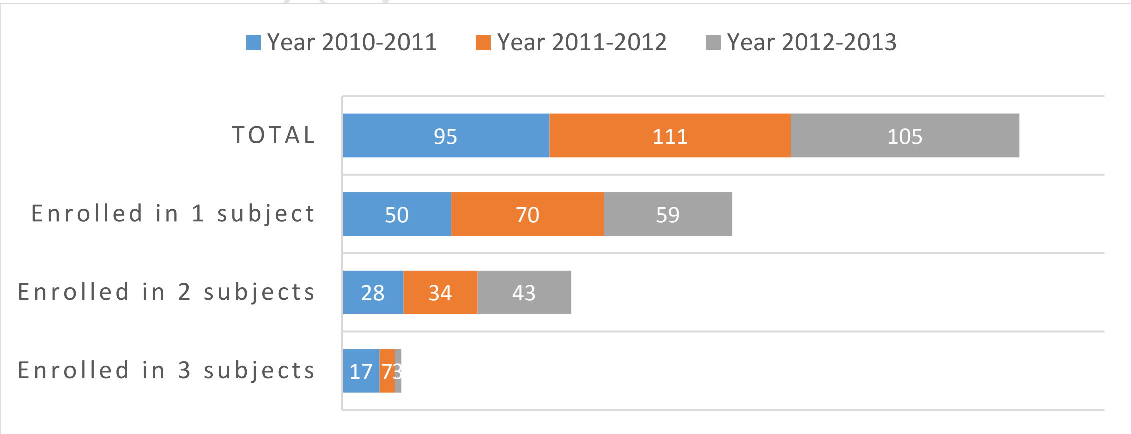


Figure 5. Distribution of the number of students enrolled in one, two or three technical subjects at the same academic year. These figures do not include the simultaneous enrollment in the subject of PM.

During those three academic years, 429 satisfaction surveys were collected at the end of the year (see details at Figure 6). This corresponds to 95.5% of the graded students, and to 91.2% of the 470 enrollments in the learning experience.

This high percentage of participation in the surveys indicates that the methodology used increases the commitment of the students (which is directly related to attendance rate) until the end of the academic year, which is in sharp contrast with the situation encountered when these subjects were taught using the previous methodology.

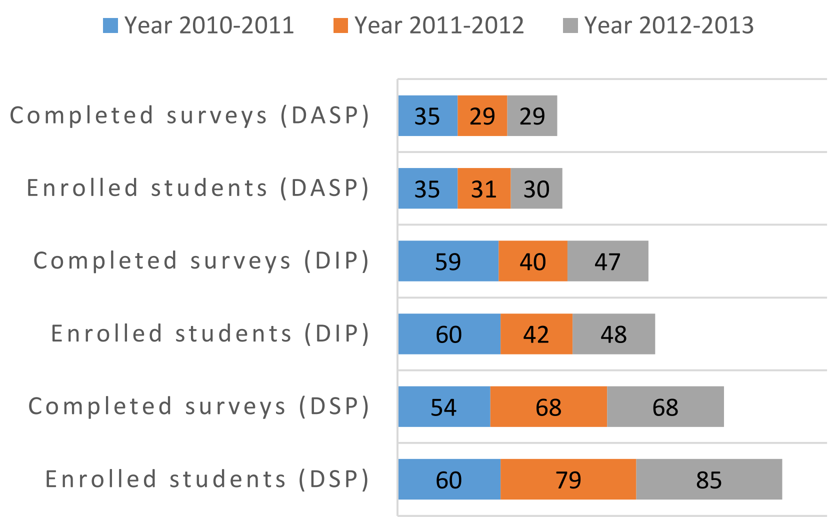


Figure 6. Distribution of the number of students enrolled by course and academic year and the respective number of surveys completed.

The survey consisted of i) 5 questions about personal and academic information (age, degree in which the student is enrolled in, previous experience in POL, number of subjects followed that year, number of simultaneous subjects within the experience), ii) 5 questions about the acquisition of soft skills (negotiation and workgroup skills, tolerance and friendship with respect to peers, work planning), iii) 4 questions about the required dedication and the overall functioning of the course (e.g. workload comparison with classic methodologies, quality of the provided documentation), iv) 2 questions about the mentoring process (usefulness, evaluation of its importance to solve group conflicts), v) 2 questions about the POL-based methodology (degree of concepts understanding and of motivation to learn), vi) 3 questions about global satisfaction (evaluation of the role of the experts, mentors, and overall opinion of the experience), and vii) a blank space for comments.

For the sake of brevity, in the following paragraphs we only describe the results we consider as the most relevant for the evaluation of the learning experience described in this work. In this sense, the following figures depict the results corresponding to just some of the previously mentioned questions (see each figure's caption to read the corresponding question). Moreover, we evaluated the reliability of each survey by means of the Cronbach's alpha (Cronbach, 1951), obtaining values ranging between 0.75 and 0.87, which validates the reliability of the questionnaires.

When asked about the acquisition of soft skills, 85.5% of the surveyed students indicated that the experience improved their ability to work in group (“Completely”-18.2%, “Quite a bit”-67.3%, see Figure 7). Moreover, a 79.3% of them considered that the experience enhanced values such as team spirit, friendship, solidarity and tolerance (Figure 8). Finally, 70% of the students felt that their ability to plan future work had improved thanks to the methodology (Figure 9).

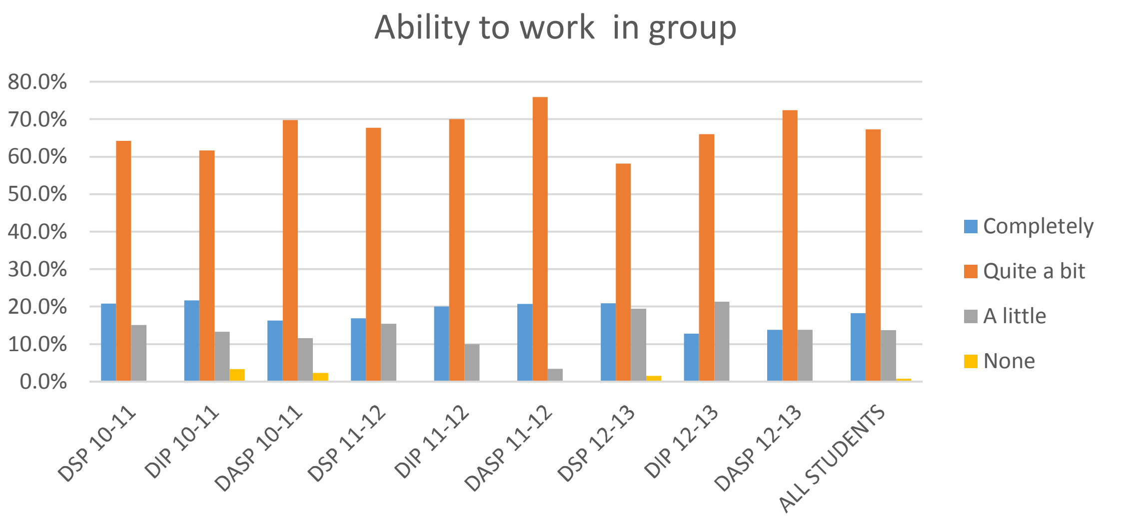
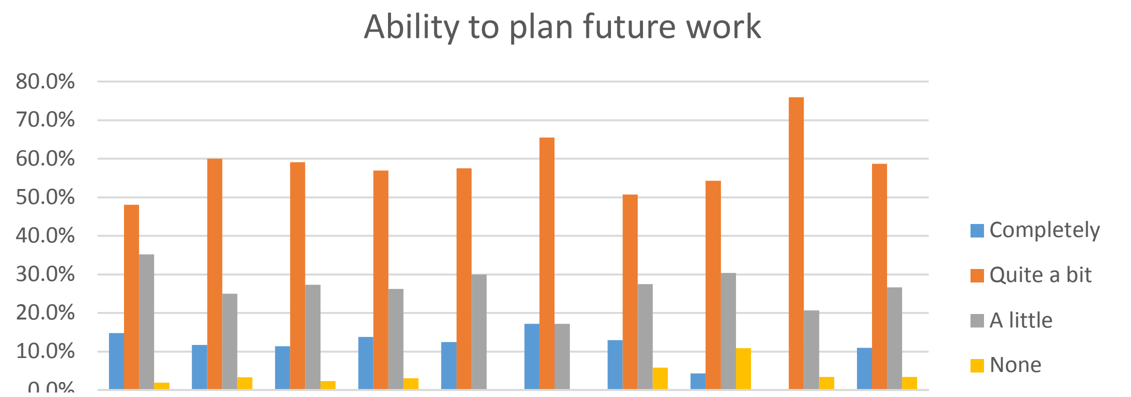


Figure 7. Results for the question *“Regarding teaching of this subject with POL methodology, do you think your ability to work in group has improved?.*

Figure 8. Results for the question *“Regarding teaching of this subject with POL methodology, do you think that values like team spirit, friendship, solidarity and tolerance have been enhanced?”*.



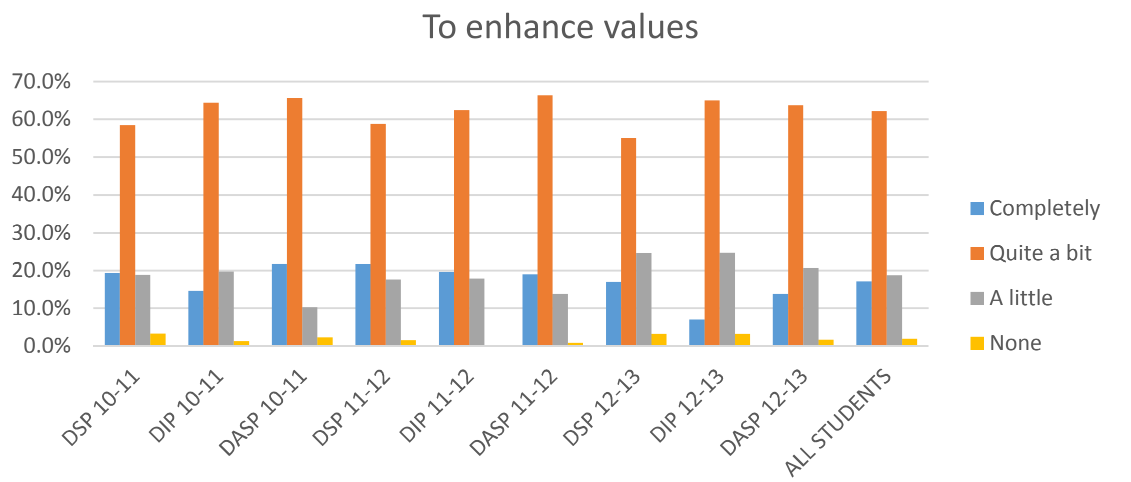


Figure 9. Results for the question *"Regarding teaching of this subject with POL methodology, do you think your ability to plan work has improved?"*.

Another interesting question asked was whether the students felt they had obtained a better understanding of the concepts when following either a POL-based or a classic learning methodology. Figure 10 shows that 64.4% of the students considered that the level of understanding was much higher or higher with POL, 15.4% answered that the level of understanding was equal under both methodologies, and only 20.1% said that it was lower or much lower. While this last figure is not insignificant, we consider that it is largely due to the answers of the DSP students. Indeed, DSP is the subject with the strongest mathematical foundation, and students sometimes struggled with that type of contents. In response to this situation, we introduced the seminars described in Section 4.7. This helped decreasing over time the percentage of students that considered that the level of understanding was lower or much lower.

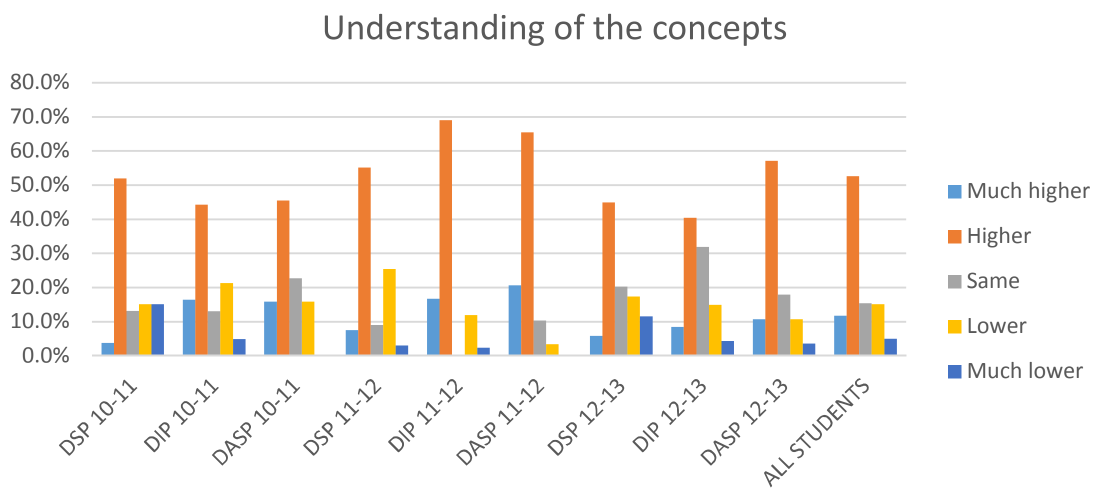


Figure 10. Results for the question *"Regarding teaching of this subject with POL methodology, do you think your ability to plan work has improved?"*.

These results indicate that the implemented learning experience is perceived by students as an improved way of learning, as it makes it easier for them to acquire the required technical skills while improving their soft skills.

Next, Figure 11 shows that 86.1% of the surveyed students prefer the POL-based methodology over classic learning methodologies.

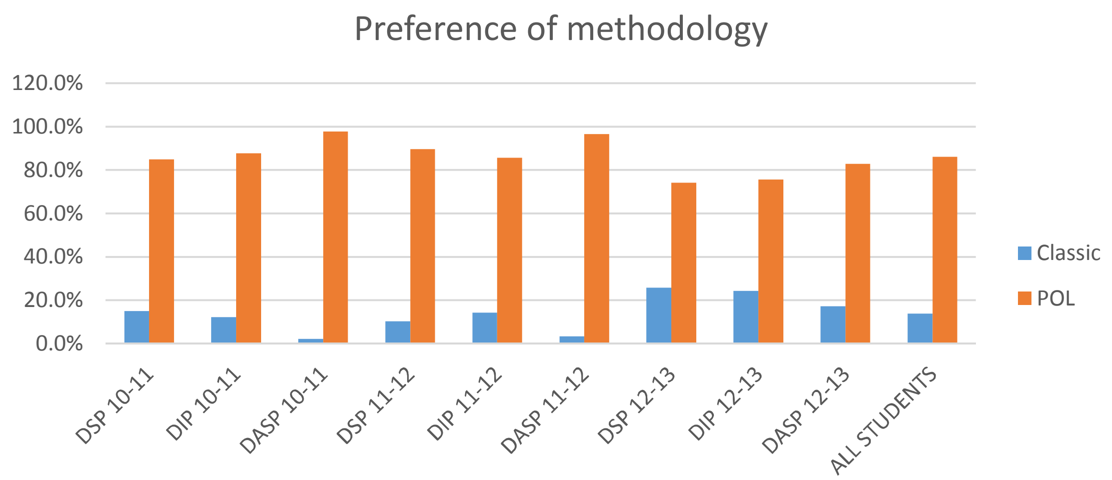


Figure 11. Results for the question *"Based on this experience, in the face of new training needs, which methodology do you prefer?"*

This indicates that students have a very positive opinion of the implemented learning experience.

However, it is also interesting to analyze the evolution of the replies to this question over time. Indeed, there is an increase in the percentage of students that prefer classic learning methodologies, despite still being much lower than that of the students preferring POL-based learning. We reckon this is due to the fact that the high workload was coupled with an individual evaluation that became stricter with the years to ensure that each student reached the expected learning outcomes.

This notion is reinforced by how they evaluate the role of the experts (Figure 12), which is graded as "Very good" or "Good" on average by 93.9% of the students (depending on the subject, this percentage ranges between 82.4% and 100%). It is important to note that the teaching staff working in the expert role was the same during the three academic years. This suggests that variations observed between academic years should be attributed mostly to the methodological changes that were gradually introduced.

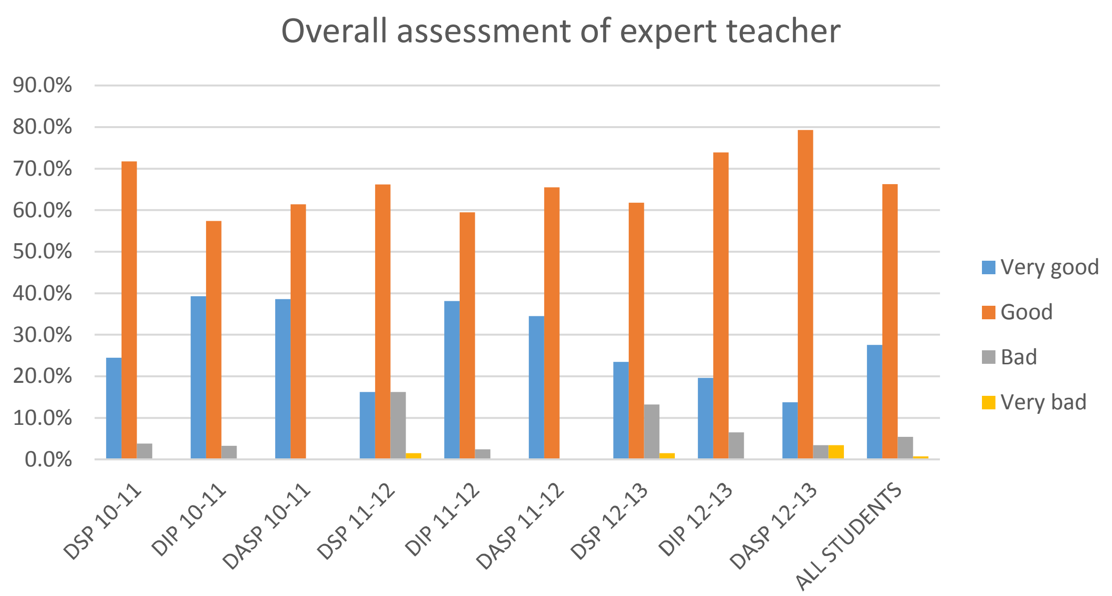


Figure 12. Results for the question *“Indicate your overall assessment of the expert teacher”*.

The role of the mentors is also very positively perceived by the students, grading it as “Very good” or “Good” by 93.7% of the students (ranging from 78.7% to 100% depending on the subject and academic year, as shown in Figure 13). This result highlights the importance and relevance of the mentor role, especially in the process of helping groups solve internal conflicts.

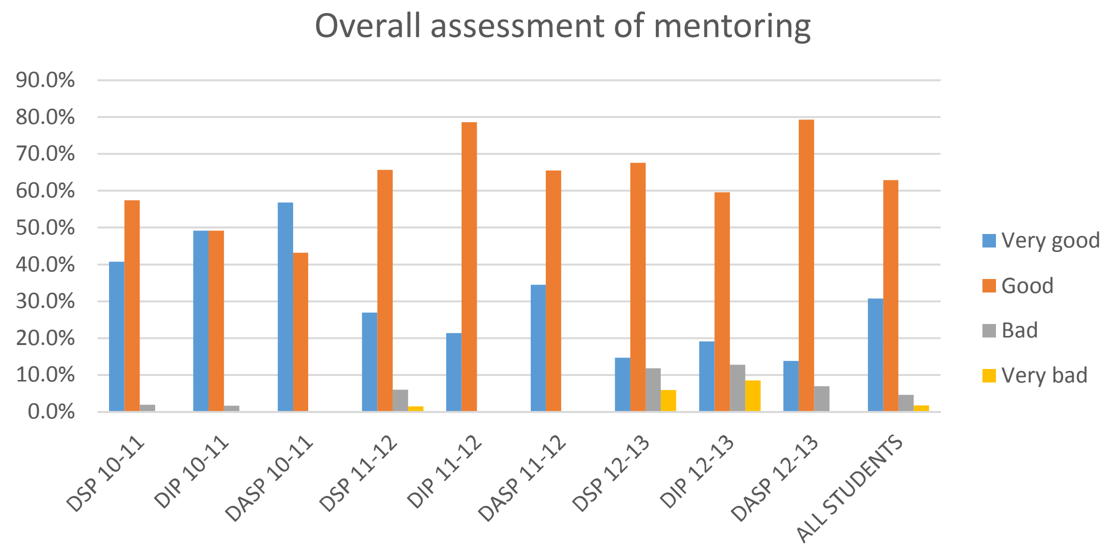


Figure 13. Results for the question *“Indicate your overall assessment of the mentoring”*.

Finally, Figure 14 shows the global evaluation of the learning experience by the students. In average, an 86.6% of the students grade it as “Very good” or “Good”, with this percentage ranging between 72.5% and 100%.

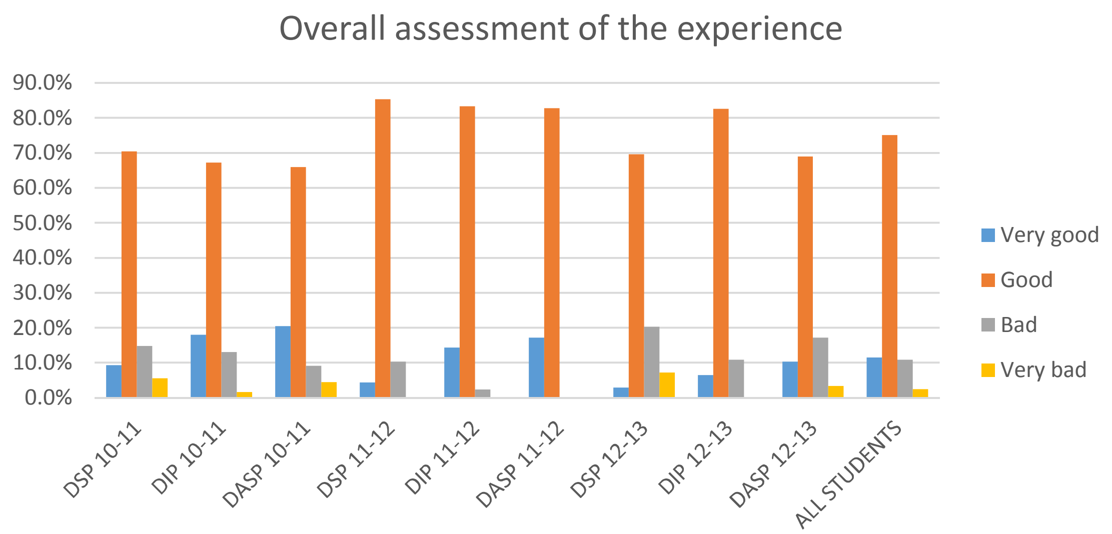


Figure 14. Results for the question *“Indicate your overall assessment of the experience”*.

An in-depth analysis of these global results allows to draw several interesting conclusions.

Firstly, if the results are analyzed on a per-subject basis, we observe that nearly 20% of the DSP students consider that the experience is “Bad” or “Very bad”. This percentage is as low as 10%

in the two other subjects. We think this difference is caused by the fact that the DSP subject requires going deeper into theoretical and mathematical contents that serve as a basis for further practical developments. Initially, the student was the sole responsible for acquiring this piece of knowledge, using the educational materials that we made available to that end. However, the complexity of the very topic made it very difficult for the students to succeed in this quest. For this reason, after the first year we introduced theoretical seminars to aid students in this area. In contrast, students in the DASP and DIP subjects show more positive opinions, possibly due to the fact that they were able to acquire the required technical knowledge by themselves given the lower level of complexity of the theoretical contents of these subjects.

Secondly, if the results are analyzed on a per-year basis, we observe that the most positive opinions were collected in 2011-12 (only a 4% of the students consider the experience as “Bad” or “Very bad”). We consider that this improvement with respect to the opinions of the previous year is caused by the fact that i) some methodological adjustments were made (see Section 4.7), and they were positively accepted by the students, and ii) many students had already experienced the methodology the previous year. However, the opinion surveys of the academic year 2012-13 show that nearly a 20% of the students perceive the experience as “Bad” or “Very bad”. This negative opinion is mostly caused by the poorer academic results obtained by the DSP students, which was possibly motivated by the higher level of rigorousness of the individual evaluation based on written exams associated to each task. Some students perceived this type of exams as beneficial in terms of their own training, but others considered it an arbitrary additional difficulty.

5.2. Former students’ satisfaction surveys

This section presents the results of a survey conducted to the same group of students that answered the surveys analyzed in Section 5.1, but 3 to 5 years after concluding their degree studies.

This latency between surveys is motivated by letting students integrate in the labor market and/or go through postgraduate studies, so they can gain perspective on how the POL-based learning methodology described in this work has influenced their skills and abilities.

First, we determined that the students that would take part in this survey would be those who had at least followed three of the four subjects involved in the experience, which amounts to a total of 132 students.

This condition is met by students who had completed at least two of the three technical subjects. We have given priority to this type of student because they lived the experience more fully than the students enrolled only in one technical subject. Therefore, we consider the answers of this group of students a strong and valuable indicator of the perceived usefulness of the learning methodology. However, we are aware that this sample provides limited evidence of the participants’ view.

Through LinkedIn profiles, we obtained the email addresses of 52 former students, who were contacted via email to complete an online survey. A total of 45 former students replied to the survey, which amounts to 86.5% of the contacted students.

The online survey consisted in 9 questions and a free comment field. Eight of the questions were equivalent to those described in Section 5.1, and the ninth question was focused on their long-term view of the experience and their current situation. Figure 15 shows the results of the analysis of the replies to the first eight questions.

Figures 15.abc present the answers to the questions regarding soft skills (ability to work in groups, work planning and values enhancement). It can be observed that the perception of students improves globally with respect to the opinion they held when they had just gone through the learning experience. In fact, the percentage of students who completely agree with the fact that the POL-based methodology improved their ability to work in group, plan future work and enhanced their values nearly doubles. In contrast, the percentage of students who disagree decreases or remains the same.

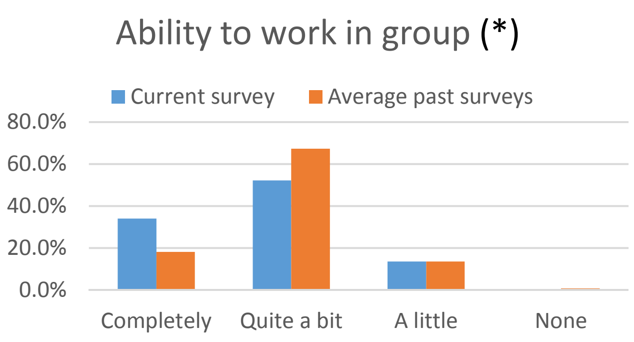
This same trend is observed when students are asked about the understanding of concepts (Figure 15.d), while the students' preference for POL-based methodologies remains stable around 80% (Figure 15.e).

As regards the evaluation of the role of experts and mentors, evaluations of "Very good" and "Good" attain combined percentages of 88.6% and 81.8%, respectively (Figures 15.fg). While these percentages are still very high, it can be observed that the opinion of students is slightly less favorable in the current surveys than in the past surveys.

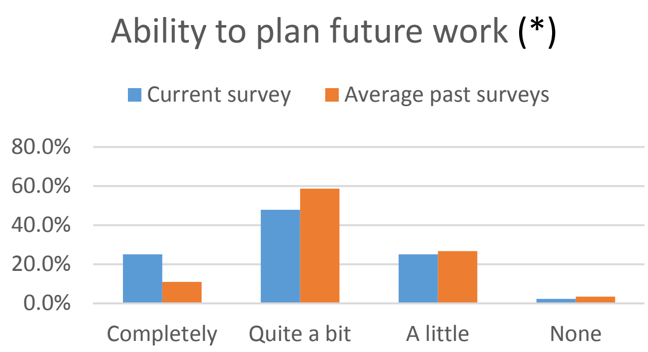
Last, the evaluation of the learning experience as a whole is more positive in the current than in the past surveys, attaining an 86.4% of "Very good" and "Good" evaluations (Figure 15.h).

We have run a non-parametric Mann-Whitney U test (Corder & Foreman, 2014) on the scores of these eight questions to evaluate whether the differences between the opinions expressed by the students in the current and previous surveys are statistically significant. This tests the null hypothesis that evaluations in both surveys are samples from distributions with equal medians, against the alternative that they are not. As a result of this test, statistically significant differences (with p-values greater than 0.05) were obtained in seven of the eight questions, which are highlighted by an asterisk in Figure 15.

With the necessary caution required by the fact that the students that answered the current survey are a sample of the global population of students, these significant differences indicate that the passing of time and the experience in the labour market has made our former students significantly improve their opinion on the skills acquired in the POL-based experience.



(a)



(b)

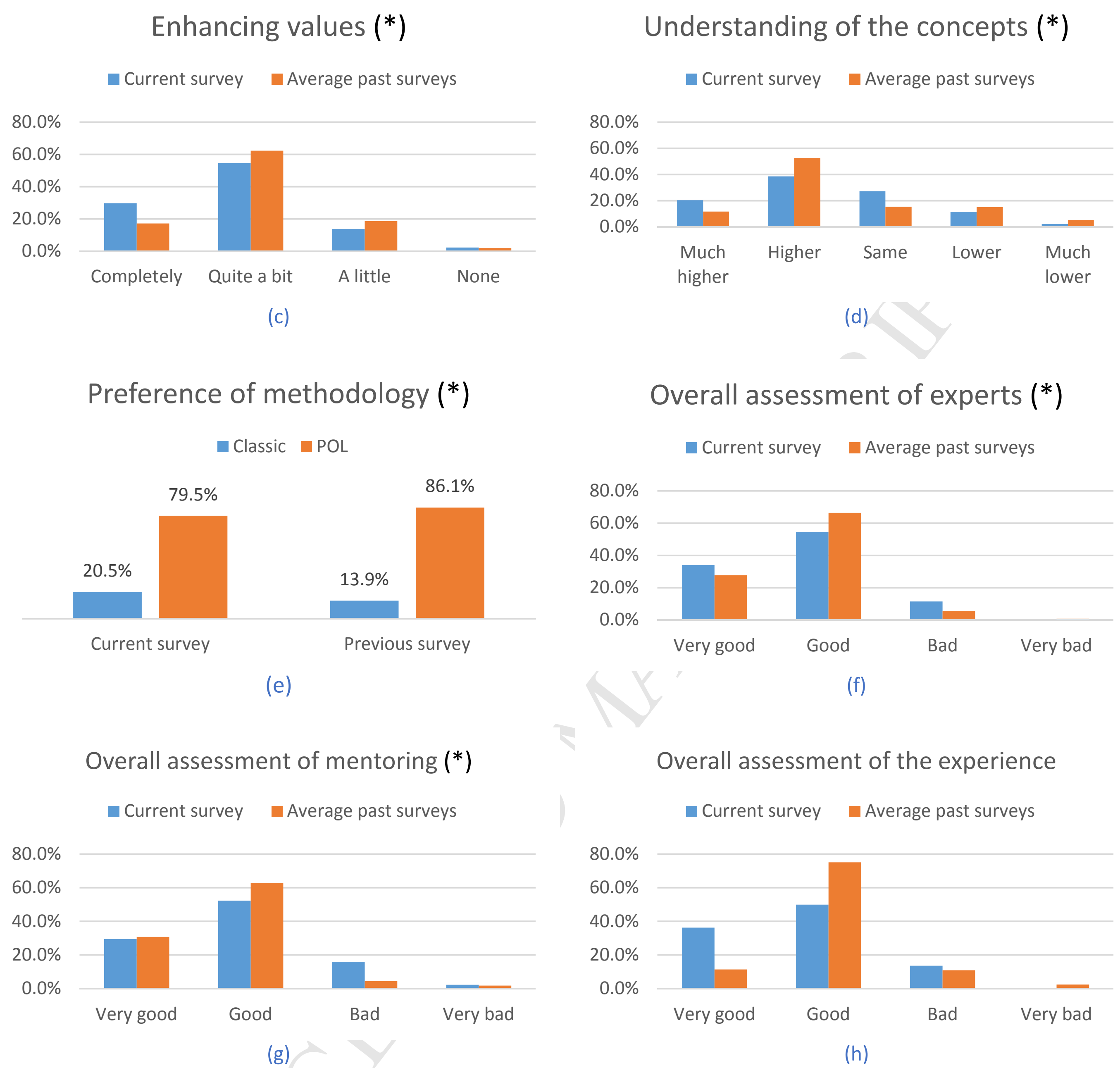


Figure 15. Comparative between the results of the current online survey and the average results of the students' satisfaction surveys performed during the three courses of the experience. The asterisk mark (*) beside each question title indicates that significant differences between the current and past surveys were found via the Mann-Whitney U test.

Finally, former students were also asked about how they remember the whole multi-course POL-based learning experience. As depicted in Figure 16, 74% of the surveyed students have either a “Very good memory” or a “Good memory”, while only 12% have a “Bad” memory of their experience.

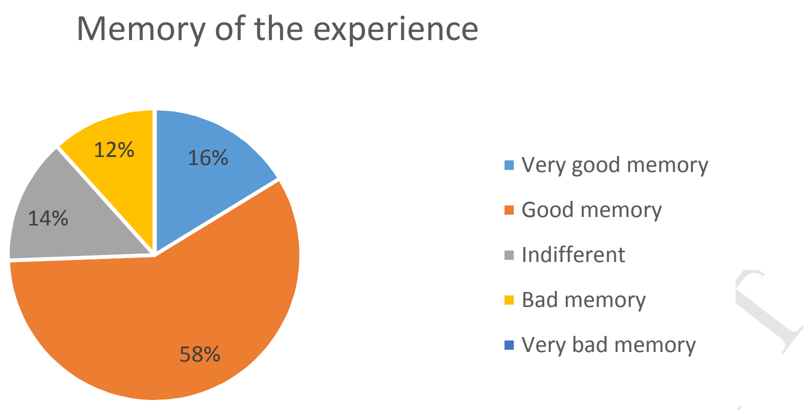


Figure 16. Results of the question "*What memory do you keep of that experience?*"

To sum up, we can conclude that with the passage of time, students evaluate the implemented experience in an even more positive way than they already did when they had just gone through it. Moreover, the reliability of this survey was confirmed by a Cronbach's alpha of 0.85.

Finally, 31 of the 45 former students that answered the online survey filled the free comments field of the online form to mainly express their gratitude to the teaching staff involved or make positive remarks that can be regarded as signs of appreciation of the experience.

5.3. Academic results

As mentioned in Section 2.2, one of the goals pursued when designing and implementing this learning experience was to increase the pass rate while reducing the dropout rate mainly in the subjects of DSP, DASP and DIP.

In the two academic years prior to the implementation of the experience (i.e. 2008-09 and 2009-10), the three mentioned subjects had a dropout rate of 20%. This rate became as low as 2.9% (on average) during the three years of the case study.

As regards the pass rate, the average rate of students failing at least one of the three subjects was 10.5% prior to the implementation of the experience and dropped to 3.9% during the three years of the case study.

All things considered, the average pass rate of all three courses combined raised from 71.7% (in the two years prior to the implementation of the experience) to 93.3% in the three years evaluated in the case study.

Thus, the proposed methodology successfully achieved both main academic goals: indeed, the need to keep up to date with work, which is inherent to POL-based experiences, was a clear factor that motivated students and made them perceive the need to attend classes and not drop out of the subjects.

One may think that the lack of written exams, or the application of more relaxed evaluation criteria could be the cause of these better academic results. In this sense, one of the questions of the survey that the students had to complete at the end of each academic year asked them to compare the workload of the courses in this experience and the courses taught using classic methodologies. On average, 89% of the students answered that the workload was "Much higher” or “Higher” under the POL-based methodology. Moreover, it is important to indicate that the surveys were completed by the students before they were given their final course grades, so it was not influenced by the academic results they had achieved.

6. Conclusions

This work has described the design, implementation and evaluation of a learning methodology based on the ideas and concepts of Constructionism. In particular, we describe the case study corresponding to three years of implementation of this methodology.

One of the main novelties of this learning experience is that it comprised four different technical and management subjects included in the ICT engineering degree curricula of the School of Engineering at SALLE-URL. The whole experience was centred on the construction of a learning artifact in the shape of a third-person shooter videogame, the interaction capabilities of which had to be enhanced by the students working in groups. By learning the basics of emergent technologies like 3D audio, computer vision or speech recognition, the students were able to fulfil the requirements of a client in a simulated corporate scenario, which stimulated the engagement of the students by being involved in a common goal with their workgroup colleagues.

To evaluate the students’ perception of the proposed learning experience, students completed two separate surveys over time. One, just at the end of each academic year. And the second, 3 to 5 years after completing their graduate studies, once all of them were integrated in the labor market. This two-fold surveying strategy follows the goal of analyzing both the short and long-term views of students as regards their learning experience under this methodology.

The former surveys allowed the teaching staff to introduce several adjustments in the implemented project-oriented learning methodology year by year. Moreover, the results of these surveys were encouraging in the sense that, although students said that the new methodology required a greater dedication than traditional (oral lecture based) methodologies, they still preferred it. In global terms, the yearly surveys showed that students were very satisfied with the proposal. The latter surveys results indicate that, once integrated in the labor market, our former students still value highly the technical and soft skills acquired during the described learning experience.

As regards the academic results, the comparison between the pass and dropout rates before and during the implementation of the learning experience shows that the engagement of the students is higher, and, as a consequence, the pass rate increases and the dropout rate decreases very significantly.

It is important to highlight that the implementation of this multi-subject POL based experience requires an important investment in terms of resources, especially human resources. Our experience shows that the required dedication of the teaching staff is much higher in this scenario than when a classic learning methodology is applied. Thus, this is a key aspect to be taken into account for anyone interested in the implementation of this type of methodologies.

Another relevant issue that must be taken into consideration is the depth of the learning achieved by students. In this sense, we reckon that the deployment of POL-based learning experiences must include strategies to ensure that each student reaches the desired learning results. For this reason, after the first year, we complemented group performance assessment with individual evaluation tests upon the completion of each task.

Moreover, it is also necessary to highlight that moving from classic to POL-based methodologies sometimes requires redefining and adapting the expected learning outcomes of the subjects. In this sense, in our case we had to redefine those outcomes related to soft skills, which thanks to shifting to a POL-based methodology were more clearly detailed. Moreover, some specific soft skills (like the ability to work in groups or plan tasks ahead of time) were introduced as new learning outcomes. Also, from the technical skills viewpoint, the learning outcomes were slightly adapted to solve computer-based problems instead of written exercises.

To conclude, we believe that the learning experience presented in this work that the correct implementation of constructionist dynamics in the classroom, coupled with the construction of learning artifacts, improves the motivation, the academic and the learning results (both in terms of technical and soft skills) of the students.

In this sense, the positive evaluation of this experience encouraged the design and implementation of Master studies (in particular, the Master of Science in Telecommunication Engineering) in SALLE-URL following POL-based methodologies to a large extent. In this master, up to six subjects have been designed as either technological-based projects (e.g. data/wireless/optic networks, signal/image processing, sensors/robot/app programming) or corporate-based projects (e.g. project management, entrepreneurship, technological consultancy). In these projects, students work in groups of three. Moreover, most of the teaching staff in the role of experts work in corporations (i.e. they are not faculty staff), which gives the whole project a more real-life approach. In total, 46 out of the 60 ECTS credits coursed within the classroom (76.6%) are implemented following a POL methodology, while the rest are devoted to short seminars that complement the main projects for the development of specific technological and management skills.

Our future work plan is oriented towards (i) conducting a specific study on how the experience impacted the students enrolled in the non-technical subject (PM), (ii) making vertical analyses to evaluate to which extent the different parts of the contents of each technical subject were better understood by the students thanks to the proposed methodology, and (iii) investigate on how available digital tools can aid in the design, implementation and evaluation of this kind of experience, alleviating the workload of the teaching staff involved.

7. REFERENCES

Ackermann, E. (2001). Piaget ' s Constructivism , Papert ' s Constructionism : What ' s the difference ? *Future of Learning Group Publication*, *5*, 1–11. https://doi.org/10.1.1.132.4253

Amiel, F., Abboud, D., & Trocan, M. (2014). A project oriented learning experience for teaching electronics fundamentals. *IEEE Communications Magazine*. https://doi.org/10.1109/MCOM.2014.6979959

Arias, E., Barba-Sanchez, V., Carrion, C., & Casado, R. (2018). Enhancing Entrepreneurship Education in a Master's Degree in Computer Engineering: A Project-Based Learning Approach. *Administrative Sciences*, *8*(4), 1–17.

Badets, A. (2017). Engineering curriculum development Socialization, soft skills and professional identity construction. In *Education Excellence for Sustainable Development (SEFI 2017)*. Azores (Portugal).

Balemen, N., & Keskin, M. O. (2018). The effectiveness of project-based learning on science education: a meta-analysis search. *International Online Journal of Education and Teaching*, *5*(4).

Bell, A. V., & Hernandez, D. (2017). Cooperative Learning Groups and the Evolution of Human Adaptability: (Another Reason) Why Hermits Are Rare in Tonga and Elsewhere. *Human Nature*, *28*(1). https://doi.org/10.1007/s12110-016-9276-5

Caldeira, B. C., Morais, A. A., Mesquita, D., & Lima, R. M. (2017). Learning based on interdisciplinary projects with students from several engineering courses: Case study on energy sustainability. In *6th International Research Symposium on PBL* (pp. 447–453). Press, Aalborg University.

Calvo, I., Cabanes, I., Quesada, J., & Barambones, O. (2018). A Multidisciplinary PBL Approach for Teaching Industrial Informatics and Robotics in Engineering. *IEEE Transactions on Education*. https://doi.org/10.1109/TE.2017.2721907

Corder, G. W., & Foreman, D. I. (2014). *Nonparametric Statistics: A Step-by-Step Approach*. *Animal Genetics*. Wiley. https://doi.org/10.1017/CBO9781107415324.004

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*. https://doi.org/10.1007/BF02310555

DeFillippi, R. J. (2001). Introduction: Project-based Learning, Reflective Practices and Learning Outcomes. *Management Learning*, *32*(1), 5–10. https://doi.org/10.1177/1350507601321001

Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). THE FUTURE OF ENGINEERING EDUCATION II. TEACHING METHODS THAT WORK. *Chem. Engr. Education*, *34*(1), 26–39. https://doi.org/10.1.1.34.1082

Harel, I., & Papert, S. (1991). Constructionism. In *Constructionism* (p. xi, 518). Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc3&AN=1991-99006-000

Haskins, C., Stock, T., Gladysz, B., & Urgo, M. (2018). Development of a Project-Oriented and Transnational Master Course for Training the Engineering Competencies. In A. M. Madni, B. Boehm, R. G. Ghanem, D. Erwin, & M. J. Wheaton (Eds.) (pp. 1095–1106). Cham: Springer International Publishing.

Herrera, R. F. (2017). Collaborative Project-Based Learning of Environments Programming From Civil Engineering Projects. *Educare Electronic Journal (In Spanish)*, *21*(2), 1–18. https://doi.org/doi: http://dx.doi.org/10.15359/ree.21-2.10

Hung, W. (2016). All PBL Starts Here: The Problem. *Interdisciplinary Journal of Problem-Based Learning*, *10*(2). https://doi.org/10.7771/1541-5015.1604

Kamp, A. (2013). Engineering education in the rapidly changing world. *Bulletin, Pp*, *47*, 49.

Martinez-Rodrigo, F., Herrero-De Lucas, L. C., De Pablo, S., & Rey-Boue, A. B. (2017). Using PBL to Improve Educational Outcomes and Student Satisfaction in the Teaching of DC/DC and DC/AC Converters. *IEEE Transactions on Education*, *60*(3), 229–237. https://doi.org/10.1109/TE.2016.2643623

Maznevski, M. L. (1994). Understanding Our Differences: Performance in Decision-Making Groups with Diverse Members. *Human Relations*, *47*(5), 531–552. https://doi.org/10.1177/001872679404700504

McLoone, S., Lawlor, B., & Meehan, A. (2016). The implementation and evaluation of a project-oriented problem-based learning module in a first year engineering programme. *Journal of Problem Based Learning in Higher Education*, *Early View*, 1–10.

https://doi.org/10.5278/OJS.JPBLHE.V0I0.1243

Mills, J., & Treagust, D. (2003). Engineering Education, Is Problem-Based or Project-Based Learning the Answer. *Aust J Eng Educ*, *3*.

Noguez, J., & Espinosa, E. (2004). Improving learning and soft skills using Project Oriented Learning in software engineering courses. In *Proceedings of the 2nd International Workshop on Designing Computational Models of Collaborative Learning Interaction* (pp. 83–88).

Ribu, K., & Tulpesh, P. (2018). Systematic integration of project-based learning in an undergraduate human-computer interaction course: a case study. In *International Conference on Engineering and Product Design Education*.

Rosenstand, C. A. F. (2012). Case-based learning. In *Encyclopedia of the Sciences of Learning* (pp. 503–506). Springer.

Steffe, L. P., & Gale, J. E. (1995). *Constructivism in Education*. Lawrence Erlbaum. Retrieved from https://books.google.es/books?id=rz8he5AM7KcC

ACKNOWLEDGEMENTS

The authors would like to thank the General Management board members of La Salle – Universitat Ramon Llull for their support during the design and implementation of this learning experience. Moreover, we thank all the teaching staff involved in its conception, design and implementation, especially to Carles Vilella, Simó Graells, Rosa M. Alsina, Maria Alsina and Sonia Luengo.

- A videogame is the learning artefact in this Project-oriented learning experience
- Student teams from 4 courses in Engineering work in a simulated corporate scenario
- 2 satisfaction surveys analyse students' short and long-term view on the experience
- The results show that the proposed methodology increased students' engagement
- Increased engagement resulted in higher success rate and lower quit rate