IMPROVING CREATIVE PROBLEM SOLVING SKILLS IN VOCATIONAL HIGHER EDUCATION STUDENTS THROUGH INTERDISCIPLINARY PROJECT-BASED LEARNING

C. Martins[1], C. Soares[1,2], F. Marques[1], L. Gonçalves[1], S. Estrela[1]

[1]Águeda School of Technology and Management – University of Aveiro (PORTUGAL)
[2]Faculdade de Ciências e Tecnologia, Universidade Fernando Pessoa, (PORTUGAL)

Abstract

The Águeda School of Technology and Management – University of Aveiro (ESTGA-UA), in Portugal, implements since 2001 a Project-Based Learning (PBL) Model in its higher education study programs, where the key point is to stimulate students to solve real life problems in a multidisciplinary scenario. The Project-Based Learning Model implemented at ESTGA-UA explicitly intends that students acquire soft skills (teamwork, learn independently, leadership, communication skills, and entrepreneurial spirit), besides the ones specific to each study program. This model has been associated with the creation of some technology-mediated experiences capable of promoting the local and regional development. Several projects have already been implemented, namely in the area of the Web-based Geographic Information Systems (WebGIS). More recently, a new type of study programs has been introduced in the Portuguese higher education system – the vocational higher education technical study programs (short-cycle higher education). These study programs have a duration of two years and are classified as level 5 according to the European Qualifications Framework and the International Standard Classification of Education. They allow students to obtain/gather/acquire technical skills for a professional activity, respond to labor market needs and have a strong connection to the work context.

Taking into account ESTGA-UA expertise and experience in applying PBL model to higher education study programs, one implemented an iPBL approach in the context of a vocational higher education technical study program – Programming of Information Systems. Thus, this article aims to present that approach which encompasses three different courses, discuss the strengths and difficulties of integrating courses of various knowledge areas, and propose future research trending lines.

As a concluding remark one can highlight that both students and teaching team considered it was a newsworthy experience. Besides the real project client satisfaction, students showed to be motivated to continue the work, even after the end of the course, in order to put the developed application in production.

Keywords: collaborative learning, interdisciplinary learning, motivation in learning, project based learning, vocational higher education.

1 INTRODUCTION

The Project Based Learning (PBL) didactic approach was adopted in higher education during 1980's allowing students to work collaboratively and giving them the possibility to exercise a range of skills and competences [1]. Usually, PBL includes an interdisciplinary dimension which forces students to deal with several subjects. This learning approach, defined as interdisciplinary project-based learning – iPBL [2], ensures that students are stimulated to integrate ideas, connect topics and link subjects from different disciplines [3].

The School of Technology and Management of Águeda – Aveiro University (ESTGA-UA) implements since 2001 a Project-Based Learning Model in its higher education study programs, where the key point is to stimulate students to solve real life problems in a multidisciplinary scenario [4]. The Project-Based Learning Model implemented at ESTGA-UA explicitly intends that students acquire soft skills (teamwork, learn independently, leadership, communication skills and entrepreneurial spirit), besides the ones specific to each study program. This model has been associated to the creation of some technology-mediated experiences capable of promoting the local and regional development. Several projects have already been implemented, namely in the area of the Web-based Geographic Information Systems (WebGIS). Gonçalves et al. [5] describe one of those projects, where a WebGIS application

for the management of the City of Águeda public street lighting network were developed in articulation with city council, allowing the characterization of its cadastre.

More recently, a new type of study programs has been introduced in the Portuguese higher education system – the vocational higher education technical study programs (short-cycle higher education). These study programs have a duration of two years and are classified as level 5 according to the European Qualifications Framework [6] and the International Standard Classification of Education [7]. They allow students to obtain specific technical skills for a professional activity, respond to labor market needs and have a strong connection to the work context.

Taking into account ESTGA-UA expertise and experience in applying PBL model to higher education study programs, one proposed to implement an iPBL approach in the context of a vocational higher education technical study program – Programming of Information Systems. Hence, this article aims to present that approach, discuss the strengths and difficulties of integrating courses of various knowledge areas, and propose future research trending lines.

2 RELATED WORK

Problem-based approaches to learning have a long history of advocating experience-based education. Since early studies several educational theorists highlight the importance of work-based experience or real problem solving as a learning tool; students can learn both content and thinking strategies and, although PBL is not a new approach, an integrative perspective has led to renewed interest in student projects and PBL.

Projects consist of problem-focused and meaningful units of instruction that integrate concepts from several disciplines or fields of study, which can increase student interest because they involve students in solving authentic problems, in working with others and in building real solutions (artifacts). A project requires two essentials components: a problem or question that allows students to organize and drive activities which will then result in a series of artifacts or products; and a final product that addresses the driving question [8].

PBL favors projects that lie at the center of the learning process, interdisciplinary learning, and group work, which has many benefits for effective learning because it requires that students acquire and apply information, concepts and principles. Moreover, it increases their competence in thinking because they need to design plans, track progress and evaluate solutions [8]. In PBL approach, students investigate and seek resolutions to problems, acquire an understanding of key principles and concepts. PBL also places students in realistic, contextualized problem-solving environments, preparing graduates for future work because projects help to build bridges between the classroom and real-life experiences and workplace.

On the one hand, this approach leads students to work collaboratively in designing projects and, on the other hand, they have the possibility to exercise an interdisciplinary range of abilities working in collaboration [8]. In PBL contexts, students work in groups to develop projects that could include an interdisciplinary dimension, where students are stimulated to integrate ideas, to connect topics and to link aspects of different disciplines focusing on a specific project. This context represents a challenging and motivating environment for students [2].

According to Biasutti & EL-Deghaidy [2], the interdisciplinary character of the PBL is evidenced in the opportunity given to students to analyze the same issue from different perspectives with the aim of developing a broader dimension of understanding the problems. Furthermore, it also shows students how to collaborate efficiently, to be focused and engaged in a topic, providing opportunities for developing a meta-disciplinary dimension.

Due to its characteristics and the evidenced results, PBL has been adopted by various higher education institutions worldwide and is developed and implemented in a wide range of domains – which can be found in the several examples of published projects and PBL experiences [8]. It proved its strength in engaging students in the learning process and improve teaching and learning quality [9], and promote students' learning, motivations and outcomes. Several authors consider that PBL has several advantages over traditional teaching approaches and literature identifies a set of advantages: promotion and development of active involvement of students in the learning process; independent learning and teamwork; knowledge and skills integration in several disciplines (Interdisciplinary) [8]; students' auton-

omy and awareness; critical thinking processes; a positive attitude toward the subject of study; student satisfaction [2].

On the other hand, studies intertwine students motivation and cognitive engagement in schoolwork. Blumenfeld et al. consider that projects stimulate the students learning and identify some factors that affect motivation, interest and value, perceived and achieved competence, and task focus. The interest and value assigned by the students will depend on the problem and the elements of the proposed project; according to Malone & Lepper [8], it tends to be higher when the tasks are varied and include new elements; the problem is authentic, has value and is challenging; there is closure (and an artifact is created); there is choice about what and how work is done; and there are opportunities to work with others.

Students need information and material that require them to have a set of skills to accomplish the project that will be evaluated. In the process of project development and problem-solving, they are faced with mistakes that should be perceived as natural and as part of the learning process. To ensure that these factors do not negatively influence student motivation, it is essential to seek to design projects that entice students' will to achieve ambitious goals and take risks, regardless of assessment. At this point, the teacher plays an essential role in ensuring students' interest and belief in their potential and ability to carry out the project.

Students' motivation will also depend on the classroom environment, more specifically whether the focus is on learning or performance. Once again, the teacher has a key role; if he/she puts the emphasis on performance rather than on learning (for example, when he/she compares students' performances or discourages risk taking), it will condition students' overall performance [8]. The opposite can also be applied, and the emphasis placed on learning can contribute decisively to the objectives of the PBL which, according to Hmelo-Silver [10], includes helping students develop flexible knowledge, effective problem-solving skills, SDL skills, effective collaboration skills, and intrinsic motivation. These goals appear to be achieved, according to the review of literature from the 1990s carried out by Dochy et al. [11] who evaluated the long-term effects of PBL. Their main conclusion is that the implementation of PBL has an important impact (compared to the traditional system) on the development of skills, especially in process skills. Furthermore, it seems to have an effect on long-term retention of knowledge such as remembering and understanding various concepts [12] or, according to Bell, "PBL is a key strategy for creating independent thinkers and learners" because students "apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed" [13, p. 39]. One study conducted by Biasutti & EL-Deghaidy [2] about the use of Wikis as an online didactic tool to apply project-based learning in higher education reveals various advantages of group work in PBL. Among the various conclusions of the study, the authors consider that students, in terms of teamwork and collaborative learning, formed collaborative groups where they felt a sense of community and ownership of the interdisciplinary projects that they developed; it also allowed the sharing of knowledge every time members put their skills in favor of group work to create a rich and full product. Some participants highlighted the importance of shared work that is based on different contributions and experiences that each group member brings to the context and that they developed negotiating skills because group work means, often, different ideas that require a compromise as a way to achieve the desired result.

Teachers play a critical role in PBL, who act to facilitate the learning process rather than to provide knowledge. Krajcik and Blumenfeld [14] highlight the importance of giving feedback to the students throughout the project, as a way for them to improve their learning process and make their learning more effective. Students themselves are learning to evaluate their own and their colleagues' evolution by giving them constructive feedback, which makes them more active agents, both in their learning process and in their peers' learning process.

3 LEARNING METHODOLOGY

The implementation of the iPBL occurred in the first semester of 2016/2017 with 3 of the courses of the second year of the higher education technical study program – Programming of Information Systems (PIS). In the curricular unit Project in Information Systems Programming (PISP) students should apply the skills they acquired or were acquiring in other curricular units and apply them in the scope of the work in a context as close as possible to the labor reality.

Since the number of enrolled students at PISP was only 7, all of the students worked on the same

problem. Reason why a more complex problem, that could be subdivided into well-defined tasks, was proposed. The students realized the majority of the tasks related to the work management and to task division together, the remaining tasks were divided and executed by groups of 2 elements.

Many of the skills needed for the planning, execution and implementation of the solution for the problem that was proposed, were acquired in the previous year: development and implementation of algorithms; to develop a relational schema and to implement the database to a Database Management System (DBMS); object-oriented programming; client-side web programming; and, project management. However, as mentioned earlier, for this curricular unit, there are competences and skills that are being worked and acquired at the same time, such as: server-side web development; and, study and identify characteristics of information services that can be applied to a given problem.

Based on the objectives and learning outcomes of the curricular units that make up the first semester of the second year of PIS, Web Applications and Services (WAS) and Enterprise Information Systems (EIS) joined the interdisciplinary approach. In the EIS curricular unit, some of the classes were used so that students could study information systems which allowed them to identify characteristics in order to apply the work carried out in the project. Regarding the WAS curricular unit, the exercises were designed to place students in situations with technical problems similar to those they might encounter during PISP project implementation. Furthermore, part of the students' assessment at the curricular unit was based on the implementation of some of the PISP project modules.

Both WAS and EIS curricular units used the traditional assessment types. Both used tests and assignments to evaluate the students. The PISP curricular unit followed the traditional evaluation method for PBL: a final report, a public defense which includes a presentation and a discussion.

4 PROJECT'S DEVELOPMENT

The choice of the project to be implemented by the students within the scope of the curricular unit object of this study took into account the learning methodology defined in section 3. According to that methodology it was important to choose a project whose modularity make feasible the division of the problem into well-defined tasks, enabling their distribution by subgroups of students.

Moreover, it was fundamental to guarantee the interest and motivation of the students to carry out the proposed work. However, motivating students is one the most difficult academic tasks [15]. By using the proposed PBL approach and carefully choosing the project to be done by students one tried to achieve the key effects enumerated on table 1.

Table 1. Key effects to achieve with the proposed Learning Approach

Key effects to achieve
Stimulate students' **self-taught learning**
Allow students to **learn at a self-paced rhythm**
Promote **cooperation** among students
Allow students to **work in group**
Foster **sharing and reuse of knowledge**
Allow students to **deal with real life problems**
Promote students' **expectation of success**
Develop students' **spirit of healthy competition**

Next sections describe the modular project proposed to the students, the interdisciplinary learning methodology that allowed to create synergies between various courses attended by them, and their decisions in terms of technologies and software tools used during the project's development. Last section presents the motivational strategy followed by the teaching team to promote students' spirit of competition and commitment with project success.

4.1 Real Life Project

For a Higher Education Institution (HEI), and within the scope of its management tasks, the preparation of the Assessments Calendar is one of the most important ones, since various entities of the school

campus depend on it: teachers, students and faculty staff (fig. 1).

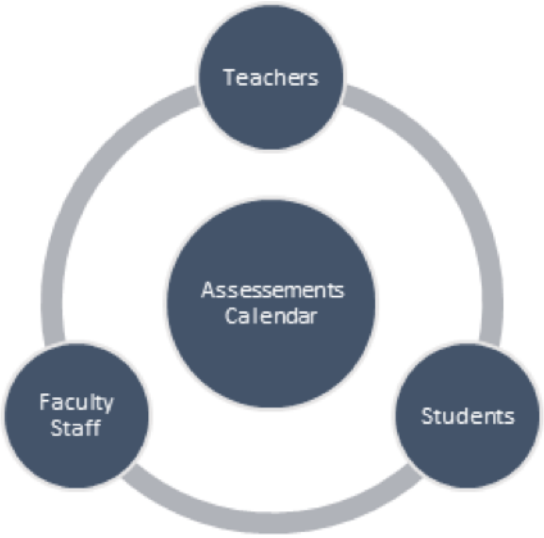

Figure 1. Management and distribution of the Assessments Calendar in a HEI

Given the high number of variables and factors to be taken into account during the preparation of the calendar, this task is particularly complex and time consuming. In fact, in addition to variables such as the number and type of rooms and labs available, number of courses and students enrolled in them, and type of assessments, it is also important to take into account the scheduling restrictions of the various teachers involved.

For the development of the project presented in this work, the teaching team proposed to the students the design and implementation of a Web application to prepare and manage the Assessments Calendar of the HEI attended by themselves. The proposed Web application should allow the deliver and consultation of the Calendar by each one of its different users in an optimized and personalized way.

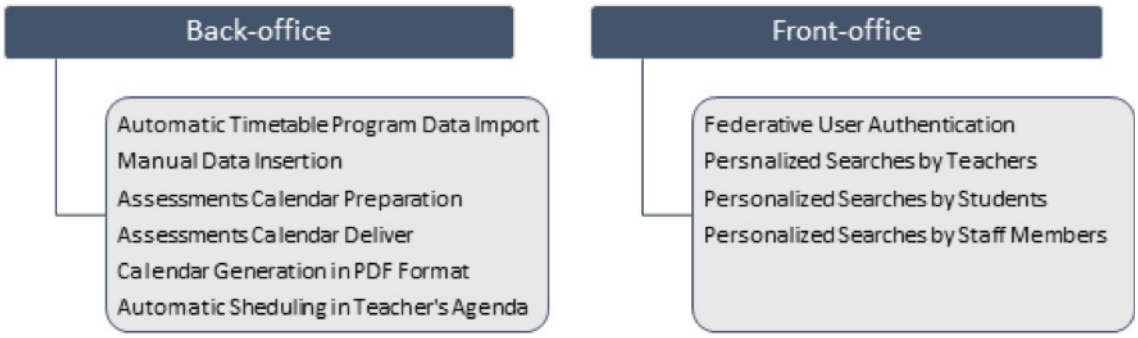

Figure 2. Modular Web Application to be implemented

The proposal contemplated the development and implementation of the two main components of that Web application (fig. 2):

- Back-office component:
  Component allowing the HEI staff to prepare the Assessments Calendar and deliver it to teachers and students in a personalized way. This component is based on information imported from the HEI timetable program in order to obtain all the data concerning the occupation of the rooms/labs and the teacher schedules. Google Calendar Web Services should be used to implement the functionality that allows the automatic scheduling of assessments in the teacher's agenda.

- Front-office component:
  Component allowing teachers and students to make personalized searches to the Assessments Calendar. For this Web application the user authentication should be performed through the HEI's federative authentication service using RESTful Web Services.

In order to ensure access to the Web application from any device (PC or mobile), its development should be based on the Responsive Web Design (RWD) paradigm.

In addition to addressing a real-life problem, the modularity of the proposed Web application allowed teamwork and cooperation among students.

4.2 Interdisciplinary Synergies

As stated in section 3 the proposed interdisciplinary learning approach was implemented in the first semester of 2016/2017, in the scope of the curricular unit Project in Information Systems Programming (PISP). By analyzing the objectives and learning outcomes defined for this curricular unit and the other four curricular units taught to students during that same semester, one defined an interdisciplinary approach encompassing the following curricular units: PISP, Web Applications and Services (WAS) and Enterprise Information Systems (EIS) (fig. 3).

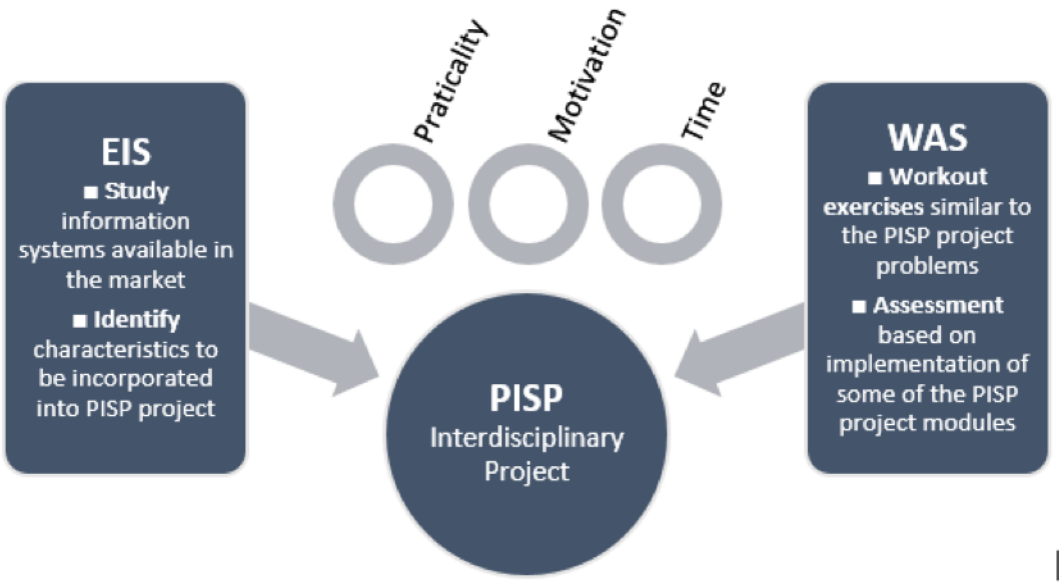

Figure 3. An interdisciplinary approach encompassing three curricular units

With this strategy one would expect that students could share, reuse and put in practice the concepts, skills and knowledge acquired both in WAS and EIS, reinforcing the practical dimension of the learning process (practicality factor). Moreover, one wanted to give students the opportunity to apply those concepts and skills in a real life context, reinforcing their motivation to learn (motivational factor). To reinforce even more this important factor one defined an additional strategy which is described in section 4.4. Additionally, this interdisciplinary approach would allow to mitigate a common problem faced by students - the overload of workout exercises and assessments that usually occurs when a traditional learning approach is applied, not allowing students to apply the time needed to develop those projects and complete these projects successfully (time factor).

Therefore, at the beginning of the semester an integrated working plan for those three curricular units was defined. Concerning the curricular unit of EIS part of the classes along the semester were used by the respective teacher to put students studying different information systems available in the market, trying to identify the best characteristics, both at the user interface level and at the system modules level, to be incorporated into the application being developed within the scope of the PISP curricular unit. In relation to the WAS curricular unit the interdisciplinary integration was carried out both at the level of

the workout exercises and at the level of the assessments. The exercises were selected so as to be similar to the technical problems arising from the implementation of the PISP project. And the students' assessment was based on the implementation (done in subgroups of two students) of some of the PISP project modules.

4.3 Collaborative and Self-Taught Learning

After the PISP project have been presented and its functional and nonfunctional requisites identified, students were given the possibility to choose the technologies and tools to use during its design and implementation.

In addition to some of the technologies, programming languages and libraries previously learned (HTML5, CSS3, Javascript, Ajax, jQuery, JSON), students opted to use for the project development the ones studied during the WAS classes (PHP, MySQL, RESTful Web Services) and others learned by them in a self-taught way. As an example, students decided to learn by them and use in their project Materialize - a modern responsive CSS framework [16]. Since one of the main objectives of the project was to promote teamwork and cooperation among students, they have been encouraged to study by themselves two of the most known and used collaborative tools: GIT – a version control system [17]; and Redmine - a web-based project management and issue tracking tool [18]. For that propose a practical workshop about GIT and its functionalities was organized and PISP students invited to participate on it. Besides those collaborative tools, and due to the heterogeneity of students' professional situation (student workers and non-workers), students selected Skype as their remote communication tool.

4.4 Motivational Strategy

As stated in Slavin [19], motivation is defined as an internal process that activates, guides, and maintains behavior over time. In the learning context, motivation influences students to choose a task, get energized about it, and persist until they accomplish it successfully, regardless of whether it brings an immediate reward [20]. So, in order to accomplish two of the key effects being achieved by the proposed learning approach - promote students' spirit of competition and commitment with project success – the interdisciplinary teaching team decided to increment student's motivation by other means beyond the ones already described in previous sections.

As a first measure the project evaluation and students' assessment were based on a final report and a public defense that includes a presentation of the work done by all the students of the group, followed by a period of discussion with a jury composed of various elements, among them the PISP teacher and an element external to the school (a person from an enterprise and with technical knowledge in the project's area). To promote students' commitment with the project success they are informed, from the beginning, about the participation of that external element in their assessment.

Moreover, to promote students' spirit of competition they were challenged to participate in a student competition evaluated by an international jury. In this case students were invited to submit a prototype of their project to the student competition integrated in SLERD, an International Conference on Smart Learning Ecosystems and Regional Developments [21]. The referred competition challenged the student community to submit projects proposals and innovative solutions, to problems related to the students' school campus, mediated by digital technologies or other suitable to solve the identified problems.

5 CRITICAL ANALYSIS

This paper describes an interdisciplinary project covering several topics learned by the students during their formation at ESTGA-UA school. The team project involved several challenges, namely, set a company like environment into the academic project evaluation. This fact forced students to reorganized their methodologies of work to be able to think, model and prototype a solution for the project detailed in previous section. The student team organized itself in sub-teams of two students, each one with specific attributed tasks, and chose a team leader to define and distribute tasks per sub-team. First, the team's elements organized themselves based on their development skills preferences. Thus, some team's members opted to work in the interface design and user experience, while others preferred to work on the database model and code programming. This organization turns during the project where students try to improve additional and different skills swapping between team and tasks specificities.

Team working leads to the fact that students are less demotivate during the project development, comparing to an approach where projects involves smaller student teams. Normally, students demotivate faster when they deal with some unknown difficulties; with larger groups, we consider that the students may interwork and help the team to pass-through difficulties, helping each other and sharing their knowledge. This work was supervised by a Professor on periodically scheduled meetings, namely for helping the student to organize and identify solutions to their difficulties.

Hence, we consider that a team working project is more motivational than working on a single student per project. We also see that the obtained results correspond and in this case exceeds the first proposed requirement list for this project. Generally, students do not keep on working in educational project after releasing the grades. However, the purpose project has also been submitted to a programming contest, which for the Students let them compared their achievement and knowledge with other students from different higher academic degrees. This fact leads the student to keep on working on the project after the end of the class semester. Another motivational factor resides in the fact that their project involves dealing with a real client, which is a member of the faculty office, and to deploy a final and functional product at the University.

We will now review what we consider the pros and cons of this interdisciplinary project approach. We consider that this approach has a positive impact on the final result of the project, which overcomes the initially defined requirements; but also on the final experience acquired individually by each student during the project development. During this project, the students feel the need for reorganizing their methodology to adapt themselves to the team working group. They review tools to use for collaborative development and management of the project, and they opt to use git for code versioning and integration. The students take the initiative to enroll in git workshops to gather knowledge on this tool.

We have identified the following as not so positive aspects, that needs to be improved in the future. The student team organization focus more their attention on technical aspects rather than on the client. More meetings and demo could have been used in the agile development strategy to involve more the client in their product development. They mainly define with the client the initial requirements of the project and at the end to present the demo.

The division made at the level of tasks was positive for the development of the group product. However, the diversity of views on the form of development led to a product whose implementation requires a better ”homogenization” and refactoring. Of course, this project was an academic work which reveals the lacks of some experienced team member to review, reorganize and adopt better methodology for team working.

6 OUTCOMES AND FUTURE WORK

In this paper an innovative experience in the context of a higher education technological study program was presented. The proposed PBL approach encompasses three different curricular units taking advantage from an interdisciplinary strategy. This learning strategy integrated those curricular units both at the level of content learning and at the level of assessments. Additionally, some motivational factors have been defined and put in practice to promote students' expectation of success.

As a concluding remark one could highlight that both students and teaching team considered it has been a newsworthy experience. Besides the real project client satisfaction, students showed to be motivated to continue the work, even after the end of the PISP curricular unit, in order to conclude the modules not yet implemented and put the application in production.

However, some issues were observed during the project development which can be addressed in future research works. First, one could conclude that some important subjects (for example, in the area of project management and collaborative work) are not sufficiently addressed on the curricular plan of the study program. This implied that students had to apply an additional effort to acquire those competences. Nevertheless, it should be noted that the students demonstrated, in the time available for the project, initiative and effort to acquire new skills, such as the use of the GIT system. Another important aspect to be taken into account in the future is the integration of the curricular unit of Technical English (TI) in the proposed interdisciplinary approach. In fact, the contribution of this curricular unit would be very productive, namely for the additional task proposed to students, i.e., their participation in the international student competition. In this case, all the documentation and materials needed for that competition could be produced in the scope of the TI curricular unit. Finally, one realizes that students should had a more

active connection with the project client along the development phase. So, in the future one have to encourage students to meet up with project client with a more regular periodicity.

Taking into account all the previous outcomes one think that it would be worthwhile to extend this interdisciplinary approach even between curricular units of different higher education technological study programs.

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