Improving Student Engagement With Project-Based Learning: A Case Study in Software Engineering

Paula Morais, María João Ferreira, and Bruno Veloso

***Abstract*— In the area of Information and Communication Technologies, in addition to the problem of engagement, students often have difficulties in learning subjects related to modeling and programming. The reasons for these difficulties are well known and described in the literature, pointing to difficulties in abstraction and logic thinking. Knowing that the value of flexible and personalized learning, teachers are changing the way they teach, using different active learning methodologies, such as flipped classroom, project-based learning, and peer instruction. This paper describes an experiment conducted to improve the learning experiences of the students enrolled in the Computer Science bachelor's degree course, attending three curricular units: Information Systems Development, Data Structures, and Web Languages and Technologies. The approach followed by the teachers used project-based learning as an active learning methodology. This methodology allows us to achieve four main objectives: (i) improve student engagement; (ii) improve learning outcomes achievement (iii) increase the course success rate and (iv) allow students to experience the need for the software development lifecycle, feeling that software engineering is not a block-based process but depending on previous activity, often leads to the need to go back in the process. The results obtained with the use of the active methodology were well accepted by the students and allowed both teachers and students to reach the objectives set.**

***Index Terms*— Students engagement, project-based learning (PBL), active learning, software engineering, requirements engineering.**

I. Introduction

NOWADAYS, the needs of students are different from those of the past. Traditional classrooms, in which students sit at desks arranged in rows in order to listen to teachers, were designed in this way to allow the latter to better transmit information to the former.

With information accessible anywhere, the role of the teacher has to go beyond transmitting the information.

In traditional classrooms students tend to lose interest, despite all the efforts of the teacher. In view of this reality, institutions are looking for strategies to involve young people and minimize the impact of this paradigm shift.

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The authors are with Research on Economics, Management and Information Technologies (REMIT), Universidade Portucalense, 4200-072 Porto, Portugal (e-mail: pmorais@upt.pt; mjoao@upt.pt; brunov@upt.pt).

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Knowing the potential of active learning strategies, teachers are changing the way they teach, using different teaching and learning methodologies, such as inverted classroom, problem and project-based learning and peer instruction [1]–[11]. These strategies share the common goal of increasing student engagement by getting them to do things, to participate actively, and to think about the things they do.

In the area of Information and Communication Technologies (ICT), in addition to the problem of commitment, students often have learning difficulties in topics related to modeling and programming. The reasons for these difficulties, are well known from the literature, pointing to difficulties in abstract and logical thinking. These problems result in high failure rates. In this area, teachers have also been adopting different strategies to minimize the referred problems [12]–[14].

This article describes an experience of using project-based learning, carried out to improve the learning experiences of students enrolled in a Computer Science degree course, attending three curricular units (CUs) in the first semester of the second curricular year, namely: Information Systems Development (ISD), Data Structures (DS) and Web Languages and Technologies (WLT).

The selection of the aforementioned course units considered the corresponding learning results and programs, which cover part of the software development cycle, namely requirements engineering and application development. The choice was also intended for students to understand the connection and dependence between the disciplines in the curriculum.

The article is structured as follows: sections II and III provide a theoretical framework, presenting the main difficulties that students experience when learning software engineering topics and discussing the use of different learning methodologies to improve their commitment and performance; section IV presents the methodology, V describes the context and objectives of the case study; section VI introduces an analysis of the results, and finally, in section VII the main conclusions are set out.

II. Difficulties in Learning in Software Engineering

With intense competition and rapid developments in the software industry, current employers are looking for Software Engineers who have technical and behavioral skills, such as creativity, critical thinking, leadership, and communication [15], [16]. Some of these competencies are measured by employers, through examples of challenging academic projects that required, among others, teamwork and critical

thinking. Thus, a course with a focus on Software Engineering (SE) should promote students' knowledge on the main topics of SE and, at the same time, should seek to develop the behavioral skills, also known in the literature as soft skills.

According to Vogler *et al.* [15], and as mentioned, soft skills differ from hard skills. The hard skills in the presented context are related to cognitive, sets of technical skills and knowledge related to the content. For their part, soft skills include the ability to collaborate with others, communicate clearly, lead effectively, and creatively solve problems and challenges. And, while relevant to all areas of knowledge, soft skills are particularly relevant in the fields of technology/engineering as well as for the professions that are emerging in the 21st century.

Preparing students for a successful SE career involves training in Requirements Engineering (RE) and programming, emphasized in the ACM / IEEE curriculum guidelines [17] and standardized in ISO / IEC / IEEE 12207: 2017 Systems and MR.

In this context, the literature demonstrates that one of the most complex tasks is the teaching of a syllabus that involves abstraction on the part of students, namely in RE and programming [18].

RE is not a simple activity, either in a teaching-learning context or in a real-life context [19]. RE comprises several activities in itself: elicitation, analysis, modeling and specification, validation, as well as requirements management [20], the purpose of which is to express, through a requirements specification document, the purpose and functionality of a software system [21], [22]. Thus, gathering, understanding, analyzing and specifying a set of requirements requires systematic, quantifiable and repeatable techniques that ensure integrity, consistency, and relevance of the requirements. These techniques are not easy for students, due to, on the one hand, the multidisciplinary nature of RE in technical terms and, on the other, the need to use soft skills, which students often lack and are resistant to develop. In this context, teaching RE starting from problem descriptions only, as a basis for building requirements specifications, is not enough; it is necessary to provide students with ways to collect information from the "owners" of the product to be developed. For this, there is a need for students to interact with these same actors [13]. At the same time, another challenge in RE is the modeling that results from the models [23]. "Models provide abstract representations of software systems that allow software engineers to focus on high-level artifacts and their relationships while ignoring the implementation details of the system" [23]. Modeling is a complex abstraction task that includes interaction and discussion. Generally, iterations are necessary to obtain models that satisfy the requirements, requiring "discussions" between students and between students and teachers until the desired solution is reached [18]. For Berre *et al.* [23] the problems in RE are: (1) students have a very limited notion of the utility of modeling since the models are abstract; (2) the models are intangible compared to the coding that gives students immediate feedback on their work; (3) many job interviews require students to have strong programming skills, with less emphasis on modeling techniques, which discourages students from learning to model.

However, teaching programming, according to the literature, has, over the years, been equally difficult and complex. The abstraction necessary for the interpretation of problems and the systematization of problem-solving processes are complex, being one of the biggest challenges faced by students, and also the most problematic, as evidenced by the high failure rates in curricular units (CU) on these topics [24], [25].

In this context, the need arises to introduce more attractive learning methodologies and use real-world problems [26], [27], to minimize the difficulties mentioned. Students must be confronted with real-life problems and teachers, or peers must provide assistance in finding the information needed to solve them.

In addition to the above, to improve learning outcomes in CUs related to IS conceptualization and programming, students need to interact with the learning environment through different ways, such as speaking, listening, reading, writing, experimenting, and thinking about their own knowledge. Active learning strategies lead teachers and students to actively participate in the learning environment, in order to explore, experiment, test and apply the knowledge acquired in the classroom to solve real-life problems and thus develop hard and soft skills, which are the ultimate goal of the teaching and learning process [28].

III. Active Learning Strategies

The traditional teaching paradigm, based on the expository method, leads students to be passive in the classroom. This behavior makes their learning depend on transcription, memorization, and repetition, without developing critical thinking, and engaging in the learning process. This reality, which causes high failure rates, has led institutions to adopt different strategies to actively involve students in the learning process.

In this context, Higher Education Institutions (HEIs) are increasingly resorting to the use of active learning strategies in the classroom, changing the paradigm from a focus on teaching to a focus on learning.

According to [8], active learning presupposes the involvement of all students in a class, calling them to do something, instead of simply watching, listening, and taking notes. These strategies lead students to do the tasks and to think about the tasks they do [29], and involve critical thinking.

In academia, there are strong advocates for using these alternatives to traditional teaching methods, but there are also skeptical teachers. Prince [30] discusses some benefits of active learning, such as student engagement, concluding that, while not being the solution to all problems, teachers should be aware of these teaching methods. Bonwell and Eison [29], [31] also conclude that these strategies can lead to better student attitudes and improvements in thinking and writing.

There are different active learning methodologies, such as: problem-based learning/projects [6], [9], [10], [32], [33], peer instruction [7], [34], [35], research-based learning [36], [37], room inverted class [1], [2], team learning or cooperative learning [38], [39].

These strategies have also been used in courses in the area of ICT, improving student learning and helping them to think critically, solve problems, improve communication skills and work as a team [12], [18], [26], [40], [41].

In the case described in this article, teachers use project-based learning, and, as such, a brief presentation of this strategy is made.

Problem-based learning is widely recognized as a successful method. This method was initially introduced at McMaster University Medical School in Canada, and since its development in the late 1960s, many different varieties have emerged, one of which is project-based learning, ABP (Project Based Learning, PBL). It should be noted that the designations of problem-based learning and project-based learning are often used interchangeably. However, the first focuses on a problem and the other on a project, which is applied in situations where there is a tangible product as a result. Another differentiating aspect is the duration, which in problem-based learning is typically two to three weeks, four at most. In project-based learning, the "work" time can vary from a few weeks to a semester, but it is usually long.

These methods adopt as a principle the active role of students in the construction of knowledge, and the starting point for learning is a problem/project that the student wants to solve [6]. Students work in teams to identify what they need to learn to solve the problem/project. The teacher's role is to act as an advisor, intermediating, and collaborating on time with the students.

According to Hmelo-Silver [10], the objectives of PBL include helping students to develop flexible knowledge, practical problem-solving, learning and collaboration skills, and intrinsic motivation. PBL, therefore, has the potential to prepare students more effectively for the future.

IV. Methodology

Knowledge of a scientific nature relies on a fact and its language, and whenever possible, science supports its theoretical axioms in observable and repeatable data. According to McMillan and Schumacher [42], scientific knowledge has approaches and techniques to guarantee the highest possible precision in the results obtained.

In any investigation, the research strategy is a relevant decision since it communicates the expected results of a study and how these results should be evaluated. The different existing research strategies are not mutually exclusive; however, it is necessary to be able to identify situations in which a specific strategy has a distinct advantage over other strategies [43]. According to Yin [43], in the case study, "how" and "why" are central questions about a set of contemporary events in which the investigator has little or no control. Additionally, for Guba and Lincoln [44], the objective of the case study approach is to report the facts, how they occurred, describe situations or facts, provide knowledge about the studied event and prove or contrast the effects and relationships present in the case.

The objective of this research is to understand in more depth how the use of active learning methods can help students achieve the learning outcomes. Taking into account the objectives of the case study stated by Yin and Guba [43], [44], it was considered appropriate to adopt this methodology.

A fundamental step in planning and conducting a case study concerns the definition of the unit of analysis, that is, the definition of the object of study [43]. Moreover, in this investigation, as mentioned, the research analysis unit is the use of PBL in the context of teaching and learning of three curricular units. The data collection process used a questionnaire survey, applied to students; statistics of student success in different academic years were also collected.

A qualitative questionnaire divided into three parts was designed. The first part consists of 16 ordinal variables focusing on the technical skills that students should develop in each CU; the second part is composed of four ordinal variables, three of which relating to the set of soft skills to be developed and one relating to the use of PBL. All these variables were evaluated on a scale from 1 to 5, where 1 means nothing and 5 means a lot. The third part consists of three open questions, in which the student expresses the positive and, negative points as well as suggestions for improvement in the use of PBL in the three CUs. Attached is the questionnaire that was distributed to students on paper. The questionnaire was delivered on the day of the oral presentation, and at the end of the presentations, the students left the questionnaires completed.

V. Case Description

The case described here was developed in the 1st semester of the academic year 2018/19, at a Portuguese university, which integrates a department that teaches courses in ICT. This case included curricular units (CUs) of the degree in Computer Science. The curricular plan of this three-year degree includes, in the 1st semester of the 2nd year, the three CUs of Data Structures (DS), Information Systems Development (ISD), and Web Languages and Technologies (WLT). The failure rates of these CUs, in 2017/18, were as follows: DS, 57 %, ISD, 58.1 %, and WLT, 53.3 %. The idea of applying the project-based learning methodology (PBL) in three curricular units surges on the previous experience of three years of applying this same methodology, successfully, in the ISD and DS curricular units.

For the selection of the courses, we take into account:
(i) the learning objectives and programs of each course; and
(ii) the phases of the software development life cycle, namely requirements engineering, design, and coding.

The DSI course unit covers the requirements engineering stage, the DE CU focuses on the design and coding stages, and finally, the LTW CU directs the competencies to the coding, testing, and validation stages.

The teachers of the three curricular units chose to apply PBL to achieve four main objectives: (i) to improve student involvement; (ii) to improve the achievement of learning outcomes; (iii) to increase the success rate of CUs; and (iv) to allow students to feel that ES is not a process carried out in independent blocks, but dependent on the previous activity, often leading to the need to step back in the process.

The choice of these three CUs would also allow students to understand the interconnection and dependence between them in the curriculum.

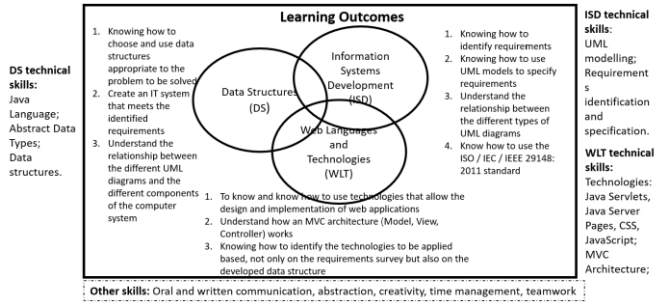

Fig. 1. PBL framework in the three curricular units.

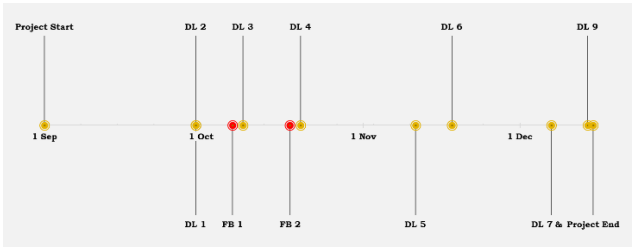

Fig. 2. Deliverables and Feedback.

The description of the case study has four subsections which describ the objectives of the project, the skills that the students would develop, the evaluation process, and the constitution of the teams.

A. Objectives

The project aimed to develop an information system to support a Jazz festival. The teachers prepared a project guide, detailing the learning objectives to be achieved and the skills to be developed by the students. Figure 1 presents the scheme included in the Guide that summarizes the objectives of the PBL application.

For each curricular unit there is a specific set of learning objectives, namely for ISD: (i) knowing how to identify requirements; (ii) knowing how to use UML models to specify requirements; (iii) understanding the relationship between the different types of UML diagrams; and (iv) knowing how to use the ISO / IEC / IEEE 29148: 2011 standard.

The DS curricular unit aims to achieve the following learning objectives: (i) knowing how to choose and use data structures appropriate to the problem to be solved; (ii) create an IT system that meets the identified requirements; and (iii) understand the relationship between the different UML diagrams and the different components of the computer system.

The WLT curricular unit aims to achieve the following learning objectives: (i) to know how to use technologies that allow the design and implementation of web applications;
(ii) to understand how an MVC architecture (Model, View, Controller) works; and (iii) to know how to identify the technologies to be applied considering the requirements elicitation and also the developed data structure.

B. Developed Skills

After defining the project, it is necessary to identify what students will learn during this PBL experience, by identifying the skills they will acquire. Each CU has a specific set of technical skills. In the CU of ISD it is the identification of requirements and modeling in UML, and in DS CU, Java language, abstract data types, and data structures. At WLT CU - PHP, CSS, JavaScript, and MVC architecture.

In addition to technical skills, students develop skills of abstraction, creativity, time management, teamwork, and oral and written communication.

C. Assessment

We decided that the evaluation would be conducted by the teachers of the three CUs and by the peers, according to the pre-established criteria in the project guide. The weight of the project in the final grade in each CU was: ISD: 50 %, DS: 20 %, WLT: 40 %.

The project envisaged the phased delivery of nine deliverables, and created moments of formative evaluation, as outlined in Figure 2. Deliverable 8 corresponded to a final report, which followed a previously defined structure and included a section on evaluation by pairs of each group member, duly justified. The final evaluation included an oral presentation, mandatory for all members of the teams.

The peer review should reflect the performance of each member of the team, and should also serve as a team management mechanism. The result would imply an increase or decrease in each student's grade, functioning as an individual correction factor within the group.

The teachers defined three moments of evaluations throughout the project. The groups were notified by e-mail (via MOODLE) to carry out peer assessment on the scheduled dates.

The peer review criteria included: (i) attendance at meetings; (ii) level of effort at work; (iii) suggestions for solutions; (iv) original contributions; (v) interpersonal relationship; and (vi) compliance with deadlines.

At the first beginning of peer review, the three teachers were present in one of the classes to explain the process and give feedback to students' questions.

An Excel file was available in MOODLE all the time, and was used to peer assessment in each of the six criteria, on a scale of 1 to 10 (1 = bad and 10 = excellent). Each element was identified by a number and fill in the corresponding block, as shown in figure 3. Each element only knew its evaluations.

For each moment, the value relative to the average was calculated for each student. In the end, the members of the group above 1.0 improved their grade, and the others lowered the grade.

After each submission, the teachers met with the teams to discuss and help to improve the teamwork.

D. Constitution of the Teams

Each group of three students would function as a team of software engineers. The groups were chosen by the students themselves, considering the CUs they attended since not all students attended all CUs. Some students attended only two

Grades given by the element	1			2	3
Grades given to the element	1	2	3		
Evaluation Criteria					
Attendance at meetings	5	6	6		
Level of effort at work	8	7	6		
Solution suggestions	9	7	8		
Original contributions	9	7	8		
interpersonal relationship	8	8	8		
Deadline accomplishments	8	8	8		
Total					

Group 2 elements:

1. Student A
2. Student B
3. Student C

Fig. 3. Example of peer review - Student A assessments in group 2, at the first assessment.

CUs, namely, some attended only ISD and WLT and others attended only DS and WLT. Those who attended two CUs were also allowed to do the same project, although the coverage of the software development cycle was different.

VI. Results

The CU classes took place from September 10 to December 19, 2018. The project was presented by the three teachers to students in September, with oral presentations scheduled for December 18.

The number of students enrolled in each CU was: ISD 33, DS 32, and WLT 37. Only 23 students did attend the three CUs (having formed eight groups, seven of three students and one of two), eight attended DS and WLT (having formed three groups, two of three students and one of two), and five, ISD and WLT (having formed two groups, one of three students and one of two).

The evaluation questionnaire was distributed to students who attended the three CUs and 15 responses were received. The students considered that the project contributed more to the development of teamwork skills and less to time management, as can be seen in Figure 4.

The project was relevant for students, as they understood better the interconnection between the topics covered in the three CUs, as well as the relationship between the different UML diagrams and the different components of a computer system.

According to the students, the realization of the project made it possible to identify the technologies to be applied, considering not only on the requirements elicitation but also the data structure developed. As can be seen in Figure 5, students considered that the use of PBL facilitated learning in the different CUs.

The students considered that the project contributed positively to the development of the specific skills of ISD and DS, as indicated in Figures 6 and 7.

Regarding the WLT CU, the project was more relevant to the development of CSS skills and creativity, contributing less to the development of Java Servlets, as shown in Figure 8.

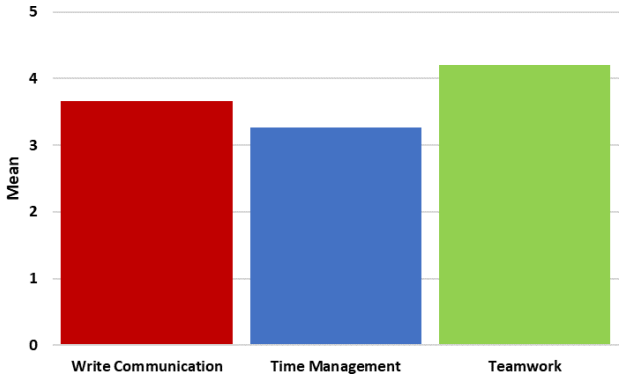

Fig. 4. Project contribution to soft skills development.

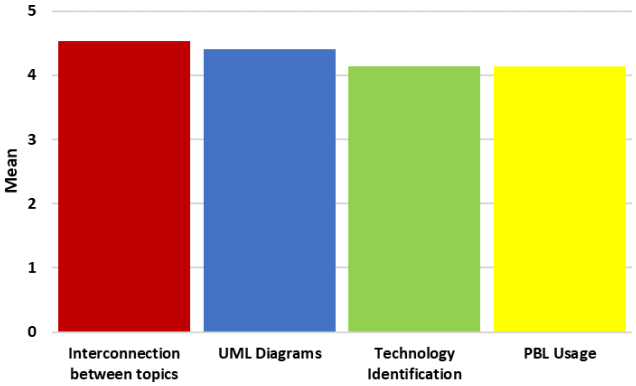

Fig. 5. Relevance and advantages of using PBL.

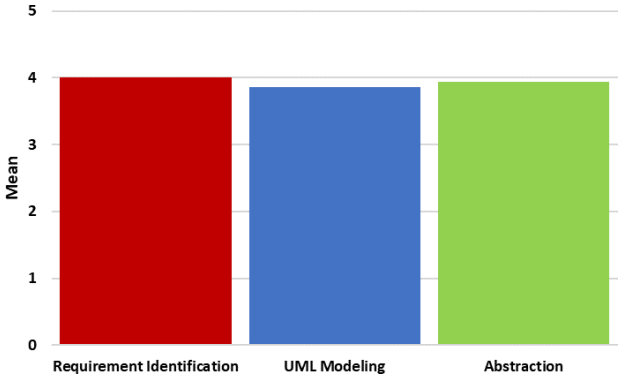

Fig. 6. Contribution of the project to the development of specific ISD skills.

The ISD approval rate was 66.7 % (41.9 % in the previous school year), DS was 62.5 % (43 % in the previous school year), and WLT was 70.3 % (46.7 % in the previous school year). In this case, it is not so relevant to compare the rate with the previous school year, since there was a change of the teacher which may also have had an impact on the rate variation.

Regarding the peer review, two groups did not make any assessment. Only two groups completed the assessment of all elements at the determined three moments. There were groups in which, at different times, some students did not evaluate themselves, nor did they evaluate peers. Almost nobody did

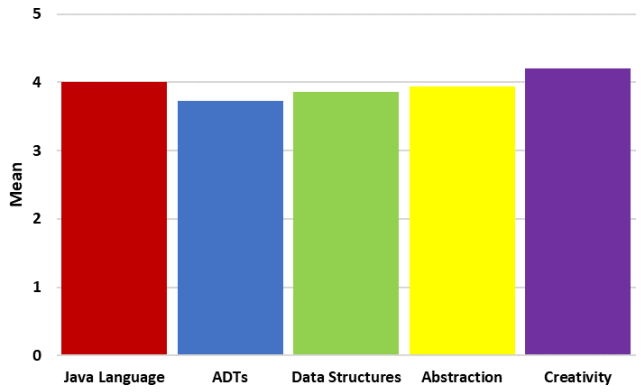

Fig. 7. Contribution of the project to the development of specific DS skills.

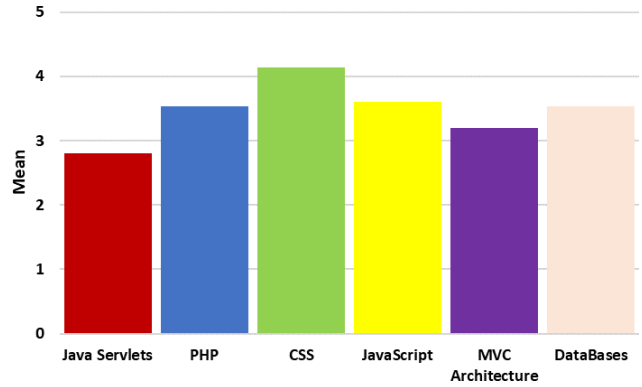

Fig. 8. Contribution of the project to the development of specific WLT skills.

the evaluation at the last moment. However, peer evaluation was not mandatory, in the sense of excluding students who did not take it. It accounts for 15 % (in 70 %) in the final report mark.

VII. Conclusion

Currently, HEIs have the so-called digital natives, students who need to be continuously motivated and challenged, and where informative classes do not meet this scenario but continue to be used by most teachers. However, this approach, as reported in literature, can cause problems. Digital students require different dynamics in the classroom. It is in this context that active learning strategies are attracting the attention of researchers and teachers in the field of ICT, as they stimulate student motivation and commitment with the tasks, where they are challenged to learn.

In the case described in this article, we found that the use of project-based learning improved the performance of students who attended the three CUs. It improved the development of technical skills and also some behavioral ones, increased the success rate of CUs, and allowed students to understand the interconnection and dependence of CUs in the curriculum.

One of the main limitations of the project was the peer review that did not achieve the expected objectives. This was caused by different reasons: immaturity of the students in applying the established criteria; reluctance to evaluate peers; lack of compliance with the established deadlines and finally, the size of the groups.

In conclusion, we can say that the results obtained show that it is possible to abandom traditional classes and create new approaches in the teaching and learning process. This allows for greater student motivation and commitment and, consequently, produces an improvement in their learning. We adopted the PBL strategy with the improvements identified through the problems found in this case study. It will be necessary to train the groups in peer review process and criteria so that they can carry it out more independently. The use of a rubric with criteria for each evaluation scale will also facilitate the evaluation process. The creation of five-student groups will allow us to minimize the impacts of incomplete evaluation, and will also enable other collaboration dynamics that will enhance the development of teamwork skills.

Appendix

This questionnaire is anonymous and aims to assess the extent to which the realization of this project, using a PBL methodology, contributed to achieving the objectives of the three curricular units.

Part 1:

On a scale of 1 (nothing) to 5 (lot), to what extent the realization of this project contributed to developing your technical skills further:

Specific to Information Systems Development (ISD)

	1	2	3	4	5
Requirements Identification					
UML Modeling					
Abstraction					

Specific to Data Structures (DS)

	1	2	3	4	5
Java Language					
ADTs					
Data Structures					
Abstraction					
Creativity					

Specific to Web Languages and Technologies (WLT)

	1	2	3		5
Java Servlets					
PHP					
Data Structures					
CSS					
JavaScript					
MVC Architecture					
DataBases					
Creativity					

Part 2:

On a scale of 1 (nothing) to 5 (lot), to what extent the realization of this project contributed to developing your soft skills further:

	1	2	3		5
Oral and written communication					
Time management					
Teamwork					

On a scale of 1 (nothing) to 5 (lot), indicate to what extent the use of PBL facilitated:

	1	2	3	4	5
Achieve the learning objectives of the different CU					
Understand the interconnection between the themes addressed in the three UC					
Understand the relationship between the different UML diagrams and the different components of a computer system					
Know how to identify the technologies to be applied based not only on the requirements survey but also on the data structure developed					

Part 3:

Regarding the use of the PBL methodology in this project, please indicate:

- Strengths:
- Negative points:
- Improvement suggestions:

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