Complete Integration of Team Project-Based Learning Into a Database Syllabus

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Abstract—Team project-based learning (TPBL) combines two learning techniques: 1) project-based learning (PBL) and 2) teamwork. This combination leverages the learning outcomes of both methods and places students in a real work situation where they must develop and solve a real project while working as a team. TPBL has been used in two advanced database subjects in Jaume I University (UJI)'s Computer Science degree program. This learning method was used for four years (academic years from 2018/2019 to 2021/2022) with positive outcomes. This study presents the project development, which includes teamwork formation, activities, timetable, and exercised learning competencies (both soft and specific). Further, the project's results were evaluated from three different perspectives: 1) teamwork evaluation by teammates; 2) students' opinions on the subject and project; and 3) subject final grades.

Index Terms—Learning competencies, peer evaluation, project-based learning (PBL), teamwork.

I. INTRODUCTION

TEAM project-based learning (TPBL) combines teamwork and project-based learning (PBL) methods. PBL is based on a project as the main axis of the learning process [1], which guides students through the development of a subject by posing a challenge that cannot be solved solely by applying superficial knowledge. In addition, PBL encourages an active and motivated student attitude since they must take decisions when proposing and defending solutions. The basic idea of PBL is to place students in real situations that require them to analyze, design, implement, and evaluate projects that have real applications, beyond the classroom examples. In this way, students will be able to apply what they have learned to solve problems in their future professional activities or propose improvements in the communities where they work.

PBL has been applied as a teaching technique in several disciplines and learning levels. It has been widely used in higher education levels [2], [3], [4], including Computer Science degree programs [5], [6], [7], [8].

Teamwork is extremely effective and appropriate in the classroom, allowing students to not only expand their knowledge and retain concepts and information over time but also develop communication skills [9], [10], [11]. Particularly, teamwork in a project is considered an essential skill to be developed during the education of new professionals [12], [13]. The combination of PBL and teamwork allows the active development of specific and basic skills, such as the collection and interpretation of information, the issuance expression of opinions and judgments, and the presentation of arguments, thus promoting the transfer of ideas and consensus.

This study not only describes the TPBL method but also investigates how it was implemented in two subjects on advanced databases at Jaume I University (UJI)'s Computer Engineering degree. In these subjects, the design of information systems (ISs) is studied in-depth by applying relational databases. The specific competencies of the subjects focus on the definition, design, implementation, and maintenance of ISs, and providing solutions to integrate problems based on Information Technology (IT).

The aforementioned specific competencies are directly related to the knowledge of real-world ISs. However, combining PBL with teamwork facilitates the achievement of learning results and encourages the acquisition of basic skills, such as problem solving, leadership, and critical reasoning. In summary, TPBL is a technique that is well suited to competencies addressed in these subjects.

This study presents the experience and results of the gradual implementation of the PBL combined with teamwork during the last four academic years (from 2018/2019 to 2021/2022), culminating in the full adoption of TPBL in the final year. Results from three different perspectives, such as 1) students' peer evaluation; 2) students' opinions on the project's impact; and 3) subject final results, were analyzed.

Section II presents the context of the project implementation. Subsequently, Section III describes the project, activities, competencies, and evaluation method in detail. Section IV analyzes and presents the results. Finally, Section V presents the conclusions of our TPBL learning experience and the issues that will be considered to continue with the presented learning method within the Educational Innovation Group, of which the signatories of this study are members.

II. BACKGROUND

The TPBL methodology presented in this study is developed within the framework of the subjects *Design of Database Systems* and *Design and Implementation of Databases*. These

subjects, are, respectively, part of the ISs and Software Engineering (SE) specializations offered in the syllabus of the *Computer Science* bachelor's degree program at UJI. Whereas IS specialization deals with information processing for organizational procedures and systems, SE focuses on developing software solutions using advanced algorithms and data structures [14]. Thus, databases play a crucial role in both specializations.

Both subjects are taught together because they share the same characteristics in their respective specializations, such as the same extension, academic year, and competencies. Students share classrooms, contents, lecturers, and evaluations.

These subjects are taught in three parts: 1) theory (12 sessions of 1.5 h); 2) problems (13 sessions of 1.5 h); and 3) laboratory practices (9 sessions of 2 h). Laboratory sessions start in the sixth week, once the needed theoretical contents have been introduced.

The evaluation of the subject is divided into the following two parts.
1) The continuous assessment (60%) consists of the following.
   a) The delivery of activities in the theory/problems sessions (20%).
   b) The delivery of the practice bulletins at laboratory sessions (20%).
   c) The development of a final team project (20%).
2) A final exam (40%).

Students must obtain at least 50% of the grade in each of the two parts to pass the course.

During the last four years, the subject's teaching staff has worked on incorporating TPBL into the teaching methodology. To achieve this, the subject's teamwork was modified, and it became a larger project, in which teams had to develop different activities throughout the three parts of the classes (theory, problems, and laboratory practices). During the project implementation, the following generic and transversal competencies, which are essential to obtaining a graduate degree in Computer Engineering at UJI, were worked on.
1) Capacity for analysis and synthesis.
2) Organizational and planning skills.
3) Oral and written communication in mother-tongue language.
4) Ability to manage information.
5) Problem resolution.
6) Teamwork promoting respect for diversity, equity, and gender equality.
7) Autonomous learning.

III. ACTIVITIES

A. Description

The set of activities designed to implement this potential learning method is divided into two groups. The first group includes simple tasks used to introduce basic database concepts. The other group involves complex activities, identified as *core activities*. These activities are studied, discussed, and performed by working teams, with the proposed project being the main axis. Core activities refer to database design covering all levels: conceptual, logical, and physical, as well as database implementation in a specific database management system (DBMS), the creation of different business rules, and a final report which includes a backup of the database. The eight core activities proposed to the students are as follows.

1) *Description of Requirements:* In the first teamwork session, the teacher assumes the role of a client and describes the company to be modeled. From this point, the team analyzes the IS requirements.
2) *Conceptual Design of the Data Model:* In this part, the semantics of the company's data are defined considering the data and the different user perspectives. The physical representation is excluded at this stage. The result is a conceptual schema.
3) *Logical Design of the Data Model:* In this activity the conceptual schema is transformed into a logical one in which the data structures of the database model are identified.
4) *Physical Design—Designing Tables:* This involves implementing the database from the logical schema defined in the previous step. This new task involves defining a set of tables and their constraints and creating them in a specific DBMS.
5) *Physical design—The Business Rules:* These rules model specific constraints on the IS for a particular company. This activity involves proposing the business rules according to the project. Each team member's activity is determined by this proposal. Then, they are implemented in the database and tested together.
6) *Physical Design—Roles and Views:* This is the third activity related to physical design. The data model is analyzed from a security and access perspective. Teams must define the roles of the different users and their views to access the data.
7) *Physical Design—Business Rules on Views:* This is the last task in the design stage. Here, the business rules are implemented based on the previously defined views.
8) *Final Delivery:* This is the final task and it matches the end of the course. At that time, the teams must deliver the project in a predetermined format, including a copy of the database implementation. A template that specifies the sections and format of the report is provided.

B. Development

The project is divided into theory, problem, and laboratory sessions throughout the academic semester. The first three core activities (description of requirements, conceptual design, and logical design) are developed in two sessions, as follows.
1) The teamwork begins in a problem session. In the classroom, each team undertakes the assigned activity by resolving its doubts with the teacher, who acts as the client. This activity can be completed outside the classroom and it must be delivered two days before the next problem session.

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TABLE I
SUMMARY OF MILESTONE ACTIVITIES AND THEIR DESCRIPTION

Type of session	Session	Core	Activity	Description
Problems	P2	CORE 1	Requirements description	The information system to be modeled is presented. Teams must define the description of requirements.
Theory	T3		Evaluation of requirements	Each team evaluates the description of two other teams. At the end of the activity, a common description is available for all teams.
Problems	P3	CORE 2	Conceptual design	Each team develops its conceptual design based on the requirements description.
Theory	T4		Evaluation of conceptual design	Each team evaluates the conceptual design of two other teams. Each team continues with its proposal. Discrepancies are resolved on the blackboard.
Problems	P4	CORE 3	Logical design	Each team models the logical design from the conceptual design.
Homework	H1			Development of the proposed model in an SW tool.
Homework	H2	CORE 4	Physical design	The physical part of creating tables starts from the logical design.
Laboratory	L2		Database implementation	The physical design is implemented in the laboratory. In addition, data must be entered.
Laboratory	L3	CORE 5	Triggers. Integrity rules	In the session, a trigger is created to control project's integrity rules. Each team member prepares a different trigger.
Laboratory	L4		Triggers for audits	An audit trigger is created to keep track of the update operations. Changes to the database introduced by different users must be registered.
Laboratory	L5		Triggers. Business rules	This practice session is focused on the development and implementation through triggers of different business rules of the project. Each team member prepares a different trigger.
Laboratory	L6	CORE 6	External schemes and views	This practice session is an extension of the activity developed in the sixth problem session. The external schemes and views of the project are implemented. Each team member prepares a different schema.
Laboratory	L7		Views and triggers	In this practice session, a database update is exercised through views and triggers.
Laboratory	L8	CORE 7	Triggers and data maintenance	In this practice session, the physical design is modified and an attribute is added to a table. In addition, triggers must be generated to keep it always updated.
Homework	H3	CORE 8	Final project document	In this activity the team must produce a final document describing all project works performed done during the course. The report includes a backup of the database.

2) Then, in the first part of the following problem session, each team must perform a peer review of the solutions provided by two other teams. With this knowledge of alternative solutions to the task, students can incorporate some of the features of these alternative solutions into their proposals. The teachers, who have previously reviewed the delivered activities, discuss each team's proposed solution and offer modifications or alternatives.

Once the logical design is complete, each team must execute the next activity outside the classroom. This activity includes the physical design and the tables. The resulting database must be deployed on the database server. This activity must be completed before the next problem session.

The remaining physical design activities are distributed as follows.

1) Teams make a first theoretical proposal for an activity in the first related theory session.
2) Then, a subtask of the theoretical proposal is assigned to each team member.
3) Each team member implements his/her assigned subtask in the corresponding laboratory sessions.
4) Once the laboratory practice is completed, teams integrate all subtasks of the core activity and implement them into their database.

The final project delivery, which is the last core activity, is performed outside the classroom. The deadline for submitting the project report is the day of the final exam, which is normally two weeks after the end of the classes.

The PBL is developed in two rounds of four core activities. Every student on the team must lead an activity in each round. The first round is considered completed once all teammates have led one core activity. All the students will lead another activity in the second round.

Table I describes, per core activity, the milestone activities for the course and the distribution among homework and classroom sessions.

C. Competencies

Although evaluating the impact of the TPBL learning methodology on the development of competencies is challenging, the authors believe that some of them have been enhanced. Let us analyze the reasons for these positive effects on the basic and specific competencies under consideration. There are the following basic competencies.

1) *Analysis and Synthesis Capacity:* This competence is ensured as the work team must study the elements of the proposed project and extract the requirements for the database system. Mainly concerned with core activity 1.
2) *Management of Information Capacity:* This competence is applied when modeling the IS and database of the enterprise proposed in the project. It is mainly applied in core activities 1 and 2.
3) *Organization and Planning Skills:* The project comprises various activities with several deliverables. The members of each group must plan the different activities and distribute the work for each one. This competence is difficult to apply in subjects based on independent exercises or problems to be performed individually. It is mainly applied in the core activity 1 because students, after defining the project specification, must think about the tasks and timings for its development. In any case, this competence is exercised accross all activities, as the work distribution is required in each of them.
4) *Autonomous Learning Capacity:* The subject's basic content is taught in the classroom. However, when

applying this knowledge to a real situation, doubts, and insecurities emerge. In a long-term project, students must focus more on completing the specific learning gaps adapted to the particular case of the project. It must be considered that students have to evaluate and compare their solutions with those of other groups (core activities 1 and 2) and individual propositions within the team must be debated and integrated into the project (core activities 5–7).

5) *Problem Resolution Ability:* This basic competence can be applied both in classical teaching and in TPBL methods. The difference is that in the classical teaching case, students must work more independently and are forced to find practical solutions to the encountered problems. However, in the applied methodology, the solutions of a team will be further compared with those proposed by other groups. This competence is mainly applied in core activities 5–8.

6) *Teamwork Capacity, Respecting Diversity, and Gender Equality:* The project is divided into phases or activities. Students must plan and collaborate in all activities, implying that the capacity for teamwork is exercised. Moreover, as previously explained, all members of a group must lead at least two activities (one in each of the two rounds of the project). The activity leader is responsible for assigning tasks to the members of the group, incorporating the solutions proposed by teammates, and ensuring that the activity's objectives are met. The activities are organized in such a way that there is no discrimination in the teams and that all members play all roles.

7) *Writing Communication Capacity:* The use of this competence is ensured by the fact that the last activity, core activity 8, entails drafting a technical report on the project. This document has a bigger scope than the elaboration of independent explanations of different and unconnected exercises. The technical report contains a copy of the implementation of the database, as well as a general description of the project with explanations of the design decisions that have been made.

From the specific competencies of the Computer Science degree, the subject must achieve the following.

1) Capacity to solve problems of information integration. The exercise of this specific competence is ensured as the students must analyze the project description and provide a formal specification on which the project will be based.

2) Ability to integrate IT solutions and business processes. This is the main goal of the proposed project. This ability is significantly exerted during all project development as the students must arrive at a technological solution for the real practical case presented at the beginning of the project.

3) Ability to specify, design, implement, and maintain IS. These abilities are directly related to the activities to be developed during the project and consequently, students will improve their skills in all these aspects.

D. Students' Evaluation

During the project development, members of the teams are requested to perform a self-evaluation and to peer-evaluate the performance of their teammates by filling out a questionnaire. This questionnaire is used twice, once at the end of the two phases in which the project's activities are organized. In each round, all members of a team have already assumed the lead role of one activity. In addition, in each round, the results of these peer qualifications are sent to the students to get feedback. However, they only receive the average grade assigned by their teammates; they are unaware of the marks awarded by each member of the group.

Evaluation questionnaires among teammates have been thoroughly described in [15]. These are based on the rubric of [16], which in turn followed the proposal of [17]. In these rubrics the following teamwork soft skills are analyzed.

1) *Contribution (CO):* Proposition of ideas and improvements.
2) *Participation (PA):* Involvement in the team's goal.
3) *Manners (M):* Promotion of team's healthy discussions.
4) *Responsibility (R):* Compliance with the deadlines.
5) *Attendance (A):* Do not skip team meetings.
6) *Punctuality (PU):* Arrival on time to the team meetings.
7) *Conflict Resolution (CR):* Suggestions of new alternatives when disagreements occur in the team.
8) *Leadership (L):* Fair management of the workload distribution and motivation capability.

The questionnaire is presented through Google Forms with the Corubrics tool extension, following the example, and recommendations of [18].

Corubrics supports the rubrics-based evaluation process. Once the form with the rubric is created, it is sent to the team members, so that they can anonymously evaluate their teammates. After completing the forms, Corubrics collects the data in a spreadsheet and optionally presents charts with the results.

As previously mentioned, after each evaluation round, students receive a radar chart showing the marks awarded by the other teammates. The second radar chart, corresponding to the second evaluation round, includes the marks of the first evaluation, to highlight their progress. Note that there are two implicit evaluations.

1) The student's perspective compared with the appreciation obtained from the rest of the team.
2) The student's evolution compared with their individual evaluated performance.

In this regard, students are not only evaluated by the lecturers; instead, the results of the rubrics are used to compute part of their final mark.

The metrics obtained from the rubrics have been used to measure students' performance within their teams. Each member is expected to express their appreciations to their teammates. Rubrics' results are presented as radar charts, allowing students to be categorized. Fig. 1(a)–(c) show examples of these radar charts. The marks range from 0 to 4, with 4 being the maximum grade. Further, the red line represents

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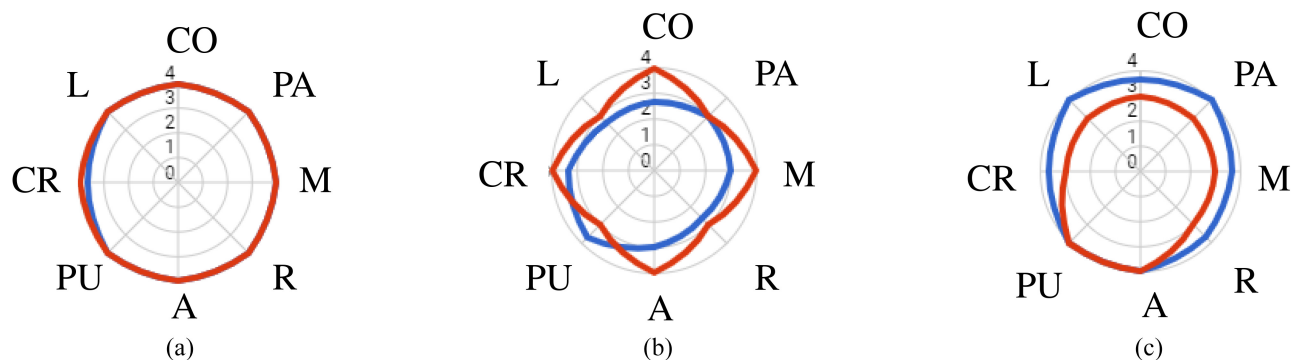

Fig. 1. Examples of radar charts illustrating the different detected behavior. Red lines correspond to the self-evaluation, while blue lines represent the results of the peer evaluation obtained by the student. (a) Fair. (b) Overestimated. (c) Underestimated.

the self-evaluation, while the blue line represents the average the rest of the teammates' peer evaluation.

These charts have allowed us to identify three categories of students.

1) *Fair:* The team members' appreciation is similar to their self-appreciation. Fig. 1(a) shows an example of this category.
2) *Overestimated:* Members of the team consider that an individual's performance is lower than their self-appreciation. This behavior may also be understood as optimistic. Fig. 1(b) shows an example of this category.
3) *Underestimated:* Members of the team consider that the individual's performance is higher than their self-appreciation. This behavior can indicate that the student undervalues their effort. Fig. 1(c) shows an example of this category.

IV. RESULTS

In the academic year 2021/22, the results of this educational experience have been analyzed from different perspectives: 1) the evaluation of the project by the teaching staff and the students' working groups; 2) the general opinion of the students about the project; and 3) the final students' marks. Further, these results are compared with results obtained from previous years.

A. Project and Teamwork Evaluation

As previously explained, each student makes a self-evaluation and is peer-evaluated by their teammates after each of the two rounds of the core activities. These evaluations provide important insight into students' evolution as the project progresses.

Fig. 2 shows the percentage of students classified into the different categories (fair, overestimated, and underestimated) in the two evaluation rounds. The figure shows an increase in overestimated students at the expense of the fair class. The differences between the two evaluations could be due to several (and probably interrelated) factors, including the following.

1) In the first questionnaire, students do not adequately evaluate their mates, assigning them extremely high values, which is difficult to overcome in the second questionnaire.
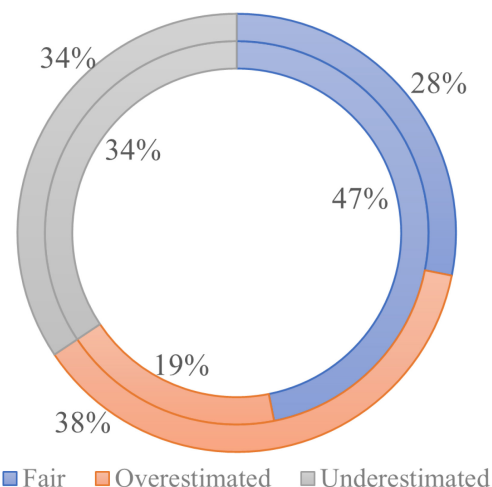

Fig. 2. Classification of students after comparing their self-evaluation with the peer-evaluation of their teammates. The inner circle corresponds to the first round and the outer circle to the second.

2) In the second evaluation round, students have a better understanding of both, their teammates and the questionnaire.
3) The workload of the students when the second questionnaire is answered is higher, not only due to this subject but also due to the addition of homework from the other subjects. Consequently, some students have reduced their participation in the working group.

Table II contains the aggregated evolution of how the students have evaluated themselves. This table classifies the evolution of the self-evaluations into three groups corresponding to students who have not changed their evaluation ("same"), others who report a decrease in performance ("worsen"), and finally those who consider that their contribution has increased ("improve"). Most students evaluated themselves equally in both rounds. Nevertheless, there are differences in some metrics. The self-evaluation for the "contribution metric" (CO) shows an increase in students who are performing worse. However, in general, students regard themselves as more punctual (PU) and better leaders (L) once they have finished the project.

In the case of the peer-evaluations, Table III shows how students have evolved from one round of evaluations to another from their teammates' perspectives. Again, the predominant
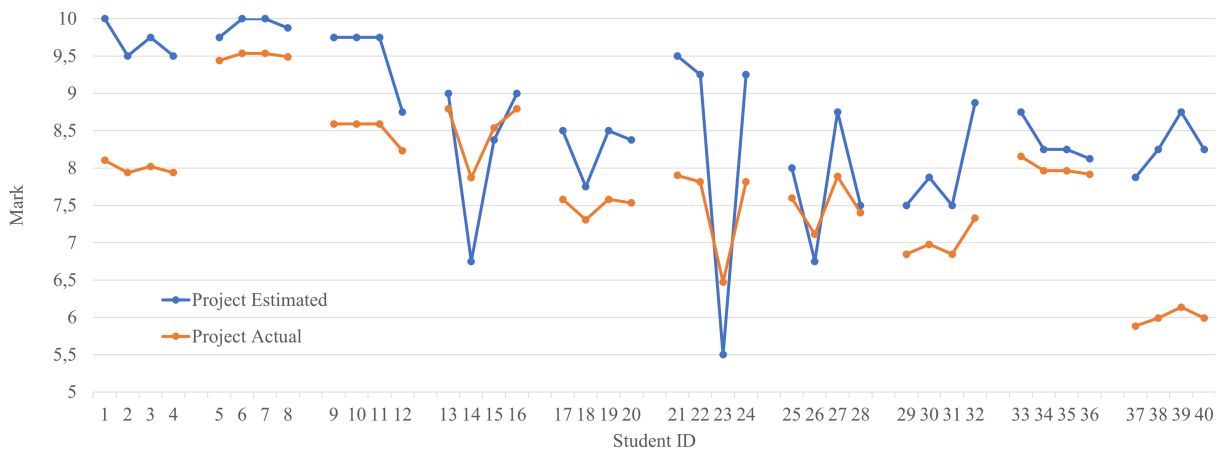
Fig. 3. Comparison of the estimated and actual marks of the project for the students grouped by their teammates.

TABLE II
EVOLUTION OF SELF-EVALUATIONS

	CO	PA	M	R	A	PU	CR	L
Same	33	32	33	30	36	34	29	32
Worsen	5	4	3	4	2	1	5	2
Improve	2	4	4	6	2	5	6	6

TABLE III
EVOLUTION OF PEER-EVALUATIONS

	CO	PA	M	R	A	PU	CR	L
Same	23	23	18	23	26	20	20	24
Worsen	8	11	10	11	11	16	8	10
Improve	9	6	12	6	3	4	12	6

Fig. 4. Difference between the averaged final and expected project marks per team.

pattern is to have the same evaluation for the two rounds. However, the "same" rate, in this case, is lower than that in the self-evaluation. Teams appreciate greater behavioral diversity among their members. Generally, the team members' performance worsens.

The students were asked to estimate their project's final mark in a final form. Fig. 3 contains the project mark (in red) and the self-estimated mark (in blue) for each student. In the figure, students are grouped by project teams.

Students expected higher marks than they received. This deviation should be studied in the future since there is not enough information to analyze this fact. However, given that the actual marks follow the patterns of the estimated marks (i.e., they seem to be correlated) a possible cause is a communication problem between the teacher and students about how the evaluation of the project.

In summary, Fig. 4 shows the difference between the average actual project mark and the expected average mark per team. Most groups were realistic about their marks since they are within the range of ±1 point. In particular, group #1 and #10 were the less realistic.

B. Students' Opinion on the Subject and the Project

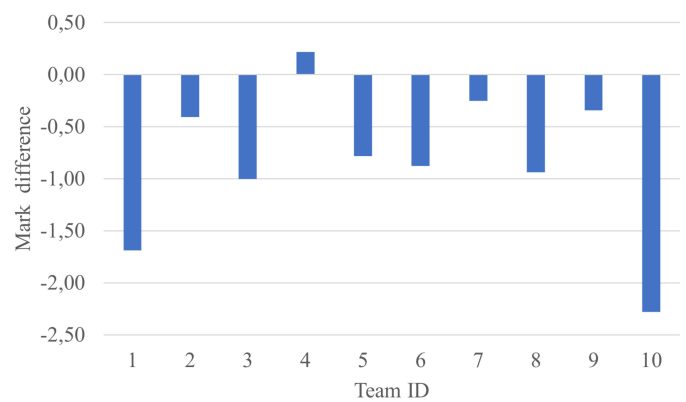During the last four years, students have completed a voluntary questionnaire to determine their opinions on both the subject and the project. This supplementary form is performed at the end of the course after the students have received their grades. The questionnaire uses a Likert scale ranging from 0 to 5, with 0 representing the maximum disagreement.

The following are the evaluation questions for the TPBL methodology and other teaching techniques used in the subjects.

1) At what point was the subject interesting to you?
2) State whether the subject has represented an excessive workload for you outside the classroom (with a score of 5 representing an excessive and unappropriated load, 3 an adequate load, and 0 no load at all).
3) Rate the methods used in theoretical lectures, which are based on deliverable exercises and peer evaluation.
4) Rate the method used in practical classes, consisting of a workbook and related exercises.
5) At what level do you consider that the project has been helpful to acquire better knowledge about the subject's contents?

Fig. 5 shows the mean values of the above questions. The percentage of students who complete this questionnaire varies between 64.5% and 71%. This figure shows that the students rated the project positively. The opinion of the students improves in successive years, probably due to the teachers' accumulated experience in TPBL.

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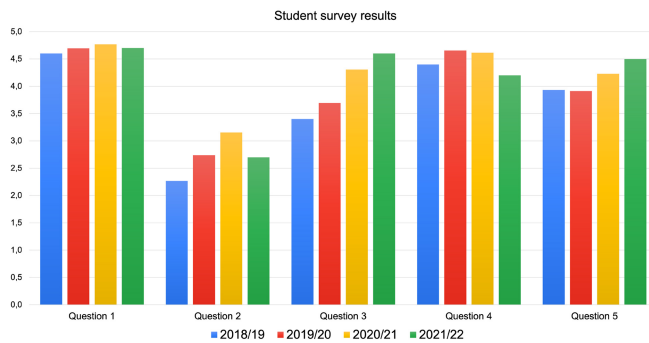

Fig. 5.   Results of the student opinion survey for four academic years.

TABLE IV
MEAN OF THE FINAL MARKS BY SESSION TYPE. THE FINAL MARK
DEPENDS ON THE WEIGHTS OF EACH PART. THE LAST COLUMN
CORRESPONDS TO THE ENROLLED STUDENTS PER YEAR

Year	Exam	Laboratory	Project	Final	%Success	Students
2017/18	5,2	8,2	7,9	7,7	65,7	35
2018/19	6,2	8,3	8,0	8,0	78,3	25
2019/20	6,5	8,8	8,3	8,3	89,7	29
2020/21	6,2	8,5	8,3	8,1	79,0	38
2021/22	6,5	7,6	7,7	8,0	80,0	40

Question 2 is designed to provide an insight into students' perceptions of the workload introduced with the TPBL methodology. Fig. 5 shows that the perception of the work to be done improves in the first three years. Thus, activities outside the classroom were reviewed and simplified. In this regard, this value has decreased in the last year. Nevertheless, students' perception of the workload remains at values close to 3, implying that it does not cost them more than they expected.

C. Final Results

Table IV presents the final results of the last five academic years, with the percentage of the students passing the subject and the number of enrolled students in the last two columns. TPBL was not introduced as a teaching methodology in the first academic year, 2017/2018, and instead, traditional academic work was done. In the last academic year, 2021/2022, only the marks of the first exam session are included, since the second exam session has not yet been done at the time of writing this article.

Table IV shows that there has been a slight improvement in the percentage of success since the TPBL methodology was implemented in the academic year 2018/2019. This upturn is mainly attributed to better results in the final exam, given that the TPBL methodology help students for a better understanding and application of concepts.

V. CONCLUSION

TPBL makes the learning process more attractive. The synergy created by combining teamwork and PBL place students in a real work situation, which a group of people must address a real problem from an organization or institution.

This study presents a PBL methodology applied to advanced database subjects. In this experience, a complete IS must be implemented for an entrepreneurial scenario. The subjects were comprehensively taught using the TPBL learning technique in the academic year 2021/2022, based on the experience obtained in previous years of PBL implementation; all sessions (theory, problems and laboratory) are focused on the problem to be solved by teams of four students.

Thanks to the different types of activities (simple and core), timetable, and teamwork, students learn subject-specific competencies and develop soft skills, such as analysis and synthesis capacity, problem resolution, autonomous learning, critical thinking, and leadership.

The results of the project development have been assessed from three different perspectives: 1) peer evaluation within groups and individual self-evaluation were performed using specific rubrics; 2) students' opinions on the project's impact in their learning outcomes regarding the subject; and 3) the subject final results.

A positive impact was observed with the adoption of the TPBL methodology. After using TPBL, final marks were slightly improved and maintained stable at around 8 out of 10. Further, the survey to know the student's perception of the use of the TPBL confirms that it helps them acquire and develop new skills. Thus, it can be concluded that the project motivates students.

The positive results observed in this teaching experience are a motivation for the ABP2INF[1] innovation teaching group to improve the Computer Science degree by applying the TPBL methodology to other subjects.

However, some issues should be reconsidered in the future. The TPBL methodology is more demanding than classical techniques for teachers' workload. When there are more than five teams, it becomes difficult for a single teacher to adequately manage the projects, as meetings and doubt-solving sessions with the teams consume a significant amount of time. A discoordination and disparity in the development of some activities (particularly core activities 5–7) have also been observed. These facts have affected the quality of the final product presented by different teams. To address this problem, specific guidelines need to be developed for the following course. Finally, delivering the project at the end of the semester, close to the exam period, has a negative effect. A way to minimize this drawback is to split the project delivery into two parts: one for the database design (after core activity 4) and the other at the end of the project including the triggers and views for the database, and the final report.

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