OmniaScience

Journal of Technology and Science Education
JOTSE, 2024 – 14(2): 324-348 – Online ISSN: 2013-6374 – Print ISSN: 2014-5349
https://doi.org/10.3926/jotse.2067

EFFECTIVENESS OF PROJECT-BASED LEARNING IN A REINFORCED CONCRETE COURSE OF CIVIL ENGINEERING

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Received January 2023
Accepted October 2023

Abstract

The application of Project-Based Learning (PBL) in a Reinforced Concrete course through the development of a real-life civil engineering project from its conception, as a coursework, is a challenged experience for students. As long as the coursework evolves, students develop real ways to think as an engineer and they work in an environment similar to that of daily engineering practice.
The effect of the PBL implementation on learning and acquisition of knowledge and skills in a Reinforced Concrete subject from the [University] in [Country] has been analyzed through some evidences such as the partial and final grades, the results of a survey and the perceptions drawn from students' interviews. As observed, thanks to the application of the PBL strategy, learning and motivation of students has increased, in addition to the final summative assessment, without a significant increase on the workload. This methodology improves not only the acquisition of knowledge and engineering skills, but also transversal skills such as entrepreneurship, leadership, communication, time management, teamwork and other social abilities directly related to those required by the current market for their future professional life.

Keywords – PBL, Real engineering projects, Reinforced concrete structures, Professional skills.

To cite this article:

Oller, E., Peña, M., & Olmedo-Torre, N. (2024). Effectiveness of project-based learning in a reinforced concrete course of civil engineering. *Journal of Technology and Science Education,* 14(2), 324-348. https://doi.org/10.3926/jotse.2067

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1. Introduction

1.1. Theoretical Framework

The change in the educational model of European universities aimed at promoting a qualitative leap in teaching-learning methodologies began with the Bologna treaty. These changes derived from different agreements reached in the European Union (EU) ended with the construction of the European Higher Education Area (EHEA). As a consequence of this process, in 2009 the Louvain-la-Neuve ministerial conference addressed the issue of student-centered learning.

The European educational context is immersed in a process of adaptation in the teaching of knowledge (Gómez-Soberón,Gómez-Soberón & Gómez-Soberón, 2009); from traditional lectures with the teacher as the only source of knowledge, to a more complete form focused on the student's know-how and accompanied by the use of Information and Communication Technology (ICT). Many universities still retain traditional methods where master lectures prevail as the main form of instruction in higher education for many teachers (Stains, Harshman, Barker, Chasteen, Cole, DeChenne-Peters et al., 2018). Recent research has identified the necessary steps towards a change in teaching-learning methodologies. These changes include improvements in long-term applicable teaching practice and a model in which the student is the center of learning. It is necessary to change the academic culture with the incorporation of active learning methodologies in the instructional practices and that this change be lasting over time and used by a wide segment of university teachers.

The convergence towards the EHEA implies a series of changes in knowledge, the ways of understanding and carrying out university training (Pastor, 2011). The planning for subjects in the new EHEA using the European Credit Transfer System (ECTS) (ABET Engineering Accreditation Commission, 2019) should consider and include some changes that can be summarized in:

- Devoting more time and effort to continuous and formative assessment than to final and summative assessment.
- Conducting assessments to improve, rather than simply monitor, learning and teaching-learning processes.
- Assessing the different types of learning and competence planned, rather than just those assessable through traditional exams.
- Valuing the learning process and its development.

The benefits of these changes in the classroom are well documented, both in terms of overall student learning (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt et al., 2014), and in terms of narrowing gaps in course grades (Beichner, Saul, Abbott, Morse, Deardroff, Allain et al., 2007; Eddy & Hogan, 2014; Haak, HilleRisLambers, Pitre & Freeman, 2011). In addition, university training should accomplish the seven quality principles of Chikering and Gamson (Chickering & Gamson, 1991): 1) to encourage contact between students and Faculty; 2) to develop reciprocity and cooperation among students; 3) to encourage active learning; 4) to give prompt feedback; 5) to emphasize time on task; 6) to communicate high expectations to students; 7) to respect diverse talents and ways of learning.

1.2. Project-Based Learning (PBL)

Among the most validated teaching methodologies, the Project-Based Learning (PBL) is an active learning methodology focused on the participation and involvement of the student in the construction of their own knowledge. It is an interdisciplinary method with an innovative approach with origins in constructivist theories (Olmedo, Farrerons & Pujol, 2021) focused on work, learning, research and reflection. The resolution of the project will involve the development and acquisition of certain competencies, skills that can subsequently be transferred to the professional environment, since one of the main objectives of this method is for the student to learn to solve a professional problem (Granado-Alcón, Gómez-Baya, Herrera-Gutiérrez, Vélez-Toral, Alonso-Martín & Martínez-Frutos, 2020). The importance of developing generic skills such as teamwork, oral and written communication, problem solving and self-directed learning (Passow, 2012; Warnock & Mohammadi-Aragh, 2016) allows students to be brought closer to the real world. According to numerous studies around the world, PBL is the most appropriate method to achieve an effective competency-based education that integrates knowledge, skills and values (Chinowsky, Brown, Szajnman & Realph, 2006; Gijselaers, 1996; Johnson, 1999; Kelly, 2007; Mulcahy, 2000; Padmanabhan & Katti, 2002; Parsons, Caylor & Simmons, 2005).

Its use in engineering courses has shown notable advantages to motivate and involve students in authentic real work situations, favoring problem solving, and developing critical thinking and professional skills (Akinci-Ceylan, Cetin, Ahn, Surovek & Cetin, 2022; Jonassen, 1997; Othman, Mat-Daud, Ewon, Mohd-Salleh, Omar, Abd-Baser et al., 2017), improving conceptual understanding and perceptions of learning (Yadav, Subedi, Lundeberg & Bunting, 2011) and academic performance (Dağyar & Demirel, 2015; Gijbels, Dochy, Van Den Bossche & Segers, 2005; Leary, Walker, Shelton & Fitt, 2013). Existing studies have emphasized the importance of integrating real-world problems into engineering classes so that students are more comfortable with complex problems when they begin their professional career (Jonassen, 1997). Students gain career motivation, students' employability improves because academia communicates to them knowledge and skills of the workforce, helping to bridge the gap between industry expectations and academic preparation (Bae, Polmear & Simmons, 2022).

PBL is a collaborative, learner-centered pedagogical approach in which students work in groups to build their knowledge and master course content. In this methodology learning occurs as a result of the effort students put into developing a project; in engineering studies they are always focused on tasks that can be performed by an engineer in professional practice. It is well known that students are more motivated and persistent in their efforts when they work in groups to carry out a project that they perceive as related to their future professional activity (Finelli, Klinger & Budny, 2001); they explore real-world problems and find answers through the completion of the project. Students also have some control over the project they will be working on, how the project will finish, as well as the final product.

In engineering education, one of the responses to the social demand for new skills has been to incorporate project-based learning (Du & De Graaff, 2009). PBL has the potential to assist students to acquire the necessary knowledge and skills required in industry today. PBL is, in various aspects, a very superior educational methodology compared to other traditional ones in engineering studies (Martinez, 2011) leading to an enhanced learning experience (Cappelleri & Vitoroulis, 2013) as it makes the delivery of both technical content and generic professional skills in a specialized course possible (Hesamzadeh, 2012).

PBL begins with the assignment of tasks that will lead to the creation of a final product. In this context, what really matters, is the learning that takes place in the process and not so much the final result. This is precisely one of the important differences between PBL and the traditional engineering final project, which puts the emphasis on the professional quality of the project outcome. Students work on open-ended assignments, that could be more than one problem. They have to analyze the problems and generate solutions; design and develop a prototype of the solution and finally refine the solution based on feedback from experts, instructors, and/or peers.

The implementation of PBL requires teamwork and therefore a higher dedication with deliverables, planning, division of responsibilities, among others. First, it is necessary to train the student in the rules of teamwork. Second, a monitoring system must be organized that guarantees work distributed over time and where all students work. Finally, it is necessary to give the necessary importance to the project grade (López & Julià, 2014).

1.3. PBL in Civil Engineering

Aalborg University (Denmark) was founded in 1974 with Project-organized Problem-Based learning in all faculties, in particular in Civil Engineering, where 50% of the curriculum is based on PBL (University of Aalborg, 1974). PBL is then the center of the curriculum; and the remaining activities are defined to help PBL. The Faculty of Civil and Environmental Engineering at the Norwegian University of Science and Technology (NTNU) at Trondheim started to introduce a PBL string in 1997, combining it with traditional curriculum. After these two first experiences, other studies related to PBL in Civil Engineering support the application of PBL in undergraduate degree programs (Gavin, 2011). Quinn and Albano (Quinn & Albano, 2008) summarized different experiences in the use of PBL in Hydraulics (Johnson, 1999), Sustainable Development (Steinemann, 2003), professional practice issues (De Camargo-Ribeiro & Mizukami, 2005), and Construction (Chinowsky et al., 2006), and developed their experience in Structural Engineering. The University College of Dublin (Gavin, 2011) develops a PBL module of case studies in Civil Engineering which is taken by the Master students to apply the theoretical principles of Structural Engineering and Soil Mechanics into practical cases.

In Spain, the Civil Engineering School of Universidad de Castilla La Mancha (UCLM) (Coronado, 2003; Escuela de Caminos de Ciudad Real, n.d.) has implemented PBL in the Bachelor in Civil Engineering, in 25% of the ECTS of 2nd year, and in 32% of the credits of 3rd and 4th year. What UCLM graduates value most is teamwork, the ability to communicate, the ability to defend ideas, team leadership, and collaborative work. In addition, according to the opinion of the graduates, the PBL does not involve loss of knowledge, and can be learned actively and applied, acquiring knowledge and practical skills and abilities.

Another example of PBL implementation is that of the University of Santiago de Compostela for civil engineers training (Castro, Nunez, Iglesias & Valcarce, 2012), where students of 2nd year work on a real civil engineering project of a transport infrastructure, which serves as a basis for developing a much more global project involving other subjects related to Geotechnical Engineering, Hydraulics and Structures. Students have the opportunity to continue their work in other subjects of the 3rd and 4th year. As stated in (Castro et al., 2012), students acquired a more global view of the specific work carried out in the different subjects, and improved the coordination between the areas of knowledge involved in the project.

1.4. Context of the Study

The curriculum of the Bachelor in Civil Engineering at the [School] of the [University] includes the Reinforced Concrete subject, which is compulsory of 3rd year (6 ECTS). In year 2019/20, there was a change in the curriculum of the Civil Engineering degree. The contents of the subject remain be the same, but the group of year 2021/22, where PBL was applied, was made up only of students adapted from the old curriculum. Its main aim is that students acquire a basic understanding of the behavior of reinforced concrete structures and develop the capacity to conceive, design, build and maintain this type of structures. For this purpose, reinforced concrete structures design and assessment procedures are dealt with, following the existing regulations (Comisión Permanente del Hormigón. Ministerio de Fomento. Gobierno de España, 2008; European Committee for Standardization, 1992).

This subject is taught with an intensity of 4 hours per week (2 sessions of 2 hours during 15 weeks) and has around 30 students per year, in one group with the same professor during the whole term. The student has previous basic knowledge of strength of materials and construction materials. The current discipline establishes a connection between these two fields of knowledge incorporating technological aspects related to construction, along with criteria related to design of reinforced concrete structures (design, assessment and arrangement of the internal reinforcement). The RC course has a basic technological character, since it is the first contact of the student with concrete structures. Being the only compulsory subject of this topic in the bachelor, it gives a global overview to achieve a sufficient basis to address the most common problems in the design and construction of reinforced concrete structures.

At the end of the course, the student must be able to understand the advantages of reinforced concrete as a material and recognize its field of application; to understand the construction phases and the behavior of structures executed with this material; to design and assess RC elements using the limit state methodology by accomplishing the conditions of safety and serviceability; and to provide appropriate measures to ensure the durability of structures.

1.5. Previous Situation to the Application of PBL

The RC subject has been largely taught in a classical way through master theoretical and problem lectures to reinforce the theoretical concepts. As the student was unaware of the topic until the class started, little interaction was observed between the lecturer and the students during the class, and the students' attitude was very passive. Although facilities were provided for students to ask questions in class and participate, few took profit. Short problems related to the verification of each limit state were solved during the course, but with a discrete global vision of a project from its initial conception. On the other hand, students carried out the corresponding assessments (two partial exams) and a group coursework. This coursework usually consists of the analysis of a structure, such if it was the sum of several short problems. Given a reinforced structure with a defined geometry, loads and materials, students obtained the envelopes of forces, and based on them, students calculated the passive reinforcement verifying the ultimate and serviceability limit states. Despite students completed the analysis of a structure, they did not conceive the project from the beginning.

In many cases, students arrived at the 3rd year with a lack of motivation and a rather passive attitude, thinking more about passing the exam than learning.

In the last years, it has been observed that students usually studied the subject in parts, depending on the partial exams, losing the global vision of the problem they will have to face during their professional life. At the beginning of the course, students took the subject daily or weekly. However, when they started having more homework assignments from other subjects, students came to class to listen but some of them did not follow the subject properly.

Students were more focused on the calculation itself, applying formulas to solve practical problems. In addition, it was difficult for them to have a critical spirit, and to analyze whether the results obtained from the problems were correct or not, and whether the order of magnitude was appropriate. The main reason is because this was the first time they faced an ill-structured problem that has not a single solution. In structural engineering, the same problem statement can have multiple correct solutions, some more optimal than others.

It was difficult for students to acquire a global vision of how to carry out a structural project from the beginning. The coursework always had a very specific bounded and marked statement related to the direct application of the existing code regulations for design. This fact had its advantages because it facilitated the development of the work by students, but it had the disadvantage that they skipped the conception design phase of the structure. In addition, to solve this coursework, some of the teams usually divided the tasks of the different sections of the statement among their peers, so that they did not acquire the overall vision initially planned. If they participated from its conception and in all its development, this work would then serve them as a guide in the final degree project, and for their future professional life.

In short, students learned to calculate, and some ended up being very good calculators, but they found very difficult to learn how to design, and also to start thinking as an engineer, which is one of our goals. To design implies more concepts and aspects than to calculate a concrete structure. A proper design requires thinking about the future: the immediate future (construction), the mid-term future (serviceability and maintenance) or the long-term future (demolition and recycling or decommission and reuse). A global strategy must be considered to ensure the durability of the structure throughout its lifetime. This affects the design of the structure, material selection, analysis, construction and maintenance.

Once students finished the RC subject, when they had to face the development of a civil engineering project, for instance the final project of the bachelor, some students were disoriented because they knew how to solve specific particular cases but it was difficult for them to move on and face the globalism of the project.

Finally, in the 4th year, some students take the optional subject of Prestressed Concrete (4.5 ECTS), which is an excellent complement for students who are interested in the project and construction of structures. The context of this subject is different, because although it is a similar topic, it is optional, and it is observed that students have a greater interest in learning (they have chosen it in their itinerary and it is not mandatory). In addition, the lower number of students, compared to the compulsory subjects, allows a greater interaction. It has been observed that at the beginning of the course, some students have forgotten some aspects of the previous course (Reinforced Concrete, 3rd year), which makes us think that these students have studied for the exam and have not assumed the concepts.

1.6. Study Objectives and Research Questions

Taking into account the didactic characteristics by developing a PBL based approach, the research questions are:

1. Did the students improve their learning and future professional skills by implementing the PBL strategy in the Reinforced Concrete (RC) subject?
2. Did the students improve their assessment in the RC subject?

To analyze the impact of PBL in the subject of Reinforced Concrete of the Bachelor in Civil Engineering at the [University], the evolution of the final grades before and after applying PBL has been studied. In addition, the exam and project grades have been analyzed for the class group. The grades of the 2015/16 academic year before PBL implementation were compared to those obtained in 2016/17, 2018/19, 2019/20 and 2020/21 academic years.

In addition, two surveys were collected during years 2016/17 and 2018/19 (after the implementation of PBL) and some interviews were conducted with students who had experienced this methodology.

The analysis of these evidences allowed to study if there is an improvement on the students learning and also on their performance. Moreover, the surveys and interviews allowed us to identify the weaknesses of this method and to propose improvements for the following editions.

Finally, this research contributes to increase the application of active methodologies in Civil Engineering, and in particular in Concrete Structures courses. It will be useful for other researchers interested in the application of PBL in subjects of Civil Engineering programs. By applying these active methodologies, it is intended to increase the interest of the students in the topic, to enhance the achievement of competences and finally, to improve the academic results.

2. Methodology

2.1. PBL implementation

In this teaching context and in order to increase motivation and active attitude of students, and to improve their critical spirit and their global vision of a structural project from its conception, more similar to the professional exercise, a project-based learning methodology was introduced in the last editions (2016/17, 2018/19, 2019/20, 2020/21, 2021/22) of the Reinforced Concrete subject. PBL was not applied during the 2017/18 academic year due to coordination reasons.

During the course, a project of a real infrastructure was developed by students in the classroom and from it, the need to explain the theory arises.

The first edition of PBL (year 2016/17) was developed with few resources, but the experience was enriching, and possible improvements and shortcomings were identified for next editions. In this case, a course project of a pedestrian bridge with a continuous reinforced concrete deck supported on piers and abutments at both ends was proposed. The footbridge should cross the AP-7 highway between Vallgorguina and Santa Maria de Palautordera (Barcelona, Spain), parallel to the existing road bridge shown in Figure 1. The theory explained in the previous class sessions was put into practice during the workshops. However, the number of workshops dedicated to the project was quite small because only a few master classes were eliminated.

Figure 1. Course project of a pedestrian bridge crossing the AP-7 highway (year 2016/17)

In the following editions, a project of a real structure has been assigned to the students during the first week of class. The aim of this project is that students learn to deal with the definition of a solution from its conception trying to understand the problem they are solving, considering not only the structural typology and geometrical contour conditions but also other aspects such as aesthetics, landscape integration, social impact. In addition, they should define the structural solution with enough details as if it was going to be built.

It is important to point out that the coursework developed by students is a real life project, that is, a project which is under public tender by a local Administration or a project which has been announced by the Administration through some media. Therefore, students are more motivated since they know that they are trying to solve a real problem. An example of this is the project of the 2018/19 academic year consisting on a pedestrian bridge at Can Quiseró (Masquefa), which is a real project tendered by Diputació de Barcelona which was built and inaugurated in 2020, as shown in Figure 2 (Diputació de Barcelona, 2020).

Figure 2. Course project of a pedestrian bridge at Can Quiseró (Masquefa)
(year 2018/19) (Diputació de Barcelona, 2020)

This coursework should be developed by working together in teams of three people. Therefore, students develop the generic skill of teamwork and in addition, they will experience the way they will work in a professional environment. During the current editions, all groups had a general common statement. The project was in a certain town, in a certain area and it was required to design an infrastructure to solve a certain need, which must be justified by students from some data provided. The structural solution was not limited, and it was allowed to students to develop the one they believe was most optimal, with a reasonable justification. Therefore, the solution proposed by each group was different, leaving them freedom to implement the solution that each group deems most convenient. For future editions, we would like to raise the possibility that the students will identify problem statements by themselves and let them try to develop an infrastructure that can solve this problem.

The full course planning was published in the virtual campus on the first day of the course, so that students were aware of when the master classes took place, and how they should progress in the project as they knew when the project workshops and partial deliveries were supposed to be.

This PBL approach required a rescheduling of the subject, so that students developed the project in class based on theoretical bases that were explained throughout the course during master classes or with supporting teaching materials. Some topics (related to the basis for design for example) were learned individually outside the classroom from the teaching material available at the virtual campus and afterwards, class activities such as online tests were carried out to check if the student has internalized the main concepts.

A significant number of face-to-face classes were devoted to conducting workshops to develop the project. These workshops were compulsory. A guided presentation was given at the beginning of the workshop and the students should work with their teams in the development of the project. Some specific objectives were advised at the beginning of each session, and the students progressed in the project development by fixing their own learning pace. In between workshops, there were master classes related to the theory required for the following workshop.

Prior to starting the project development, a site visit or seminar with a construction engineer was planned, as well as a seminar/workshop with a design engineer. During the site visit, students will set their knowledge related to the execution of structures. The seminar/workshop with a project design engineer will focus on the structural conception and the process of developing a project, rather than on the structural analysis itself. During the 2016/17 academic year, a workshop on conceptual design was held with the collaboration of engineers from the Dobooku Association (www.dobooku.com). Although the result was quite interesting, it was difficult for students to be encouraged to make proposals. Figure 3a shows a photograph during the workshop, where students were divided into groups of three or four people, to work on the approach of conceptual solutions to a particular existing problem, in this case, the need to widen a road to include a bike lane in the area where there is an existing bridge, where the existing deck needs to be widened. A conceptual map was developed, with the existing contour conditions for the definition of the solution (see Figure 3b).

a) b)

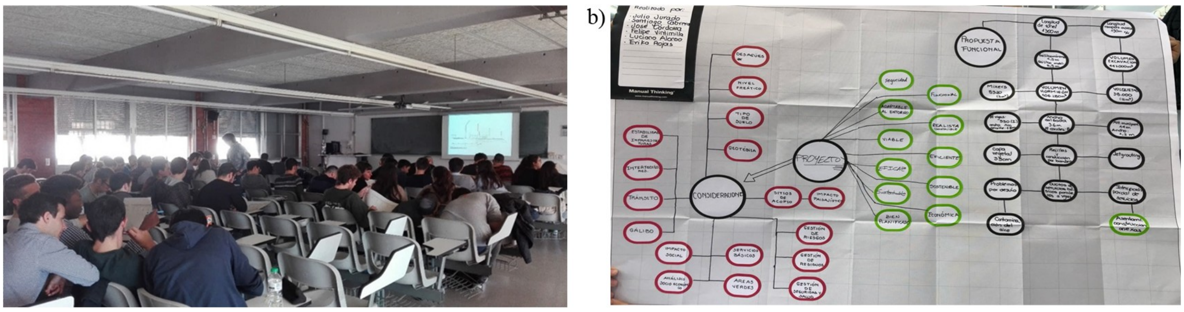


Figure 3. a) First workshop related to conceptual design (year 2016/17); b) Conceptual map developed by one of the groups (in Spanish language) during the workshop

For the following editions, this workshop has been included in the coursework development and the structural or design engineer gives a seminar explaining his/her experience and philosophy when designing structures.

The coursework was planned in three steps:

1. Conception of the structural solution;
2. Development of the structural solution:
    a. Predesign of geometry and passive reinforcement;
    b. Design of the geometry and passive reinforcement of all the structural elements. Verification of the ultimate and serviceability limit states;
3. Others: Development of plans, brief description of construction procedure, bill of quantities, and contribution to sustainability.

During step 1, the structural solution was developed conceptually, as a contest of ideas. During the first workshop, students developed a conceptual map setting down the different aspects that should be considered in a real project. Then, the conceptual solution was treated, the problem, the need for the project was identified and the main aim was to develop two or three alternatives to solve the existing need. After analyzing the landscape and by using the topographic map, students should establish a list of contour conditions. Considering the different contour conditions, students should sketch up possible alternatives, and should define the plan view and elevation of the infrastructure. Afterwards, they should choose the best alternative by a simple multiple criteria analysis.

This first step allowed the student to learn about the dynamics of PBL. Each group should establish some general rules for the teamwork that should be delivered. At the end of the semester, students should check if they and their colleagues have fulfilled all the rules and should submit this assessment. The teacher established a protocol for detecting possible problems in teams and for solving conflicts.

Once the geometry of the solution was defined, a session was held in which the different groups briefly presented their solution to the rest of the classmates, who raised possible suggestions, showing his/her critical thinking.

During step 2 as the project progresses, milestones and partial deliveries were established. In the first workshop of step 2, students should predefine the dimensions of the structural elements (deck, piers and abutments in the case of a bridge). Afterwards, students should develop a structural model in order to obtain the envelopes of axial forces, shear forces and bending moments for the ultimate and serviceability limit state combinations using a commercial program.

Then, in following workshops, teams should calculate the internal steel reinforcement accomplishing the different ultimate and serviceability limit states. During workshops, students worked with their team, applying the theory explained in class, under the supervision of the teacher. Students interacted with the teacher who gave feedback about the results they were getting during the workshop and answered all their questions. In addition, if there was the need in between workshops, each group could fix particular appointments with the teacher, to check and supervise their advances.

Deliveries of step 2 were related to: a) Establishment of the basis of design and envelopes of forces; b) Definition of the passive longitudinal reinforcement through the verification of the Ultimate Limit State (ULS) of bending with or without axial forces and of the ULS of instability; c) Definition of the transverse reinforcement by checking the ULS of shear; and d) Verification of the Serviceability Limit States (SLS) of cracking and deformation. In order to verify the ULS and SLS, students either prepared spreadsheets or were provided with existing sheets. Therefore, they were able to perform possible iterations in the solution.

These deliveries allowed the groups to carry out the work continuously over time, and not to wait until the end of the semester to develop it. In addition, the feedback given after each delivery, allowed them to arrange possible errors and make improvements during the project. The teacher could check if the whole group is working or only some of the members are working on it.

For the development of step 3, the teacher provided standard drawings of geometry and reinforcement, and a template for the bill of quantities. Drawings included the necessary details of geometry and passive reinforcement (see Figure 4 for year 2016/17). These drawings were perfectly defined in order to make a quick economic assessment.

The quantities in terms of m^3 of concrete, m^2 of formwork, and kg of active and passive reinforcement, as well as the global bill of quantities (€) were delivered at the end of step 3.

At the end of the course, students submitted a report of the analysis, drawings of the geometry, schematic drawings of internal longitudinal and transverse reinforcement distribution, the bill of quantities and a justification of the project.

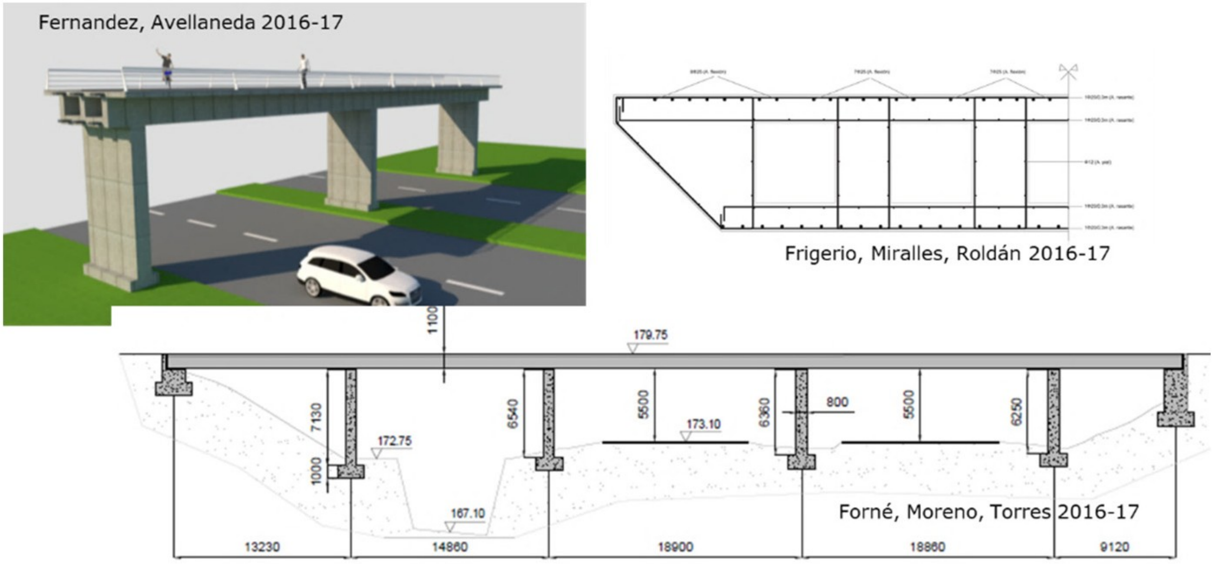


Figure 4. Example of the drawings of the geometry and reinforcement (year 2016/17)

One of the last days of the course, students presented a short summary of the structural solution to their classmates, showing the plan view, the elevation and the transverse section together with the total bill of quantities of the structure, and a short explanation about their solution, problems they solved and possible improvements on their design.

After the presentations, a class activity related to social networks was done. Students published on Twitter, some of the results related to their solution according to instructions given to them. In particular, each team tweeted 4 times. For instance, in one of the tweets, students published the main characteristics of the structural solution (number of spans, length of spans, transverse section), and in another tweet, they published volume of concrete, internal steel reinforcement ratio, and bill of quantities. Each tweet included two specific hashtags: one related to the activity and another one related to the team number. Afterwards, tweets were downloaded and compared as shown in Figure 5. Through them, we detected if there is a relevant mistake in the adopted solution, and we also identified the range for the bill of quantities and the cheapest solution. For instance, in this case Group #4 and #13 made a significant mistake in the volume of concrete (see Figure 5).

	# span	Lengths (m)	Total length (m)	Depth (m)	Concrete volume (m3)	Bill of quantities	€ /m2 deck
Group 1	5	12+15+18+19+10	74	1.25	585.0	157,424.00 €	303.9
Group 2	5	18+15,5+19+19+9	80.5	1.3	522.6	157,941.32 €	280.3
Group 3	5	13.85+14.8+18.9+18.8+16	82.35	1.2	335.4	224,716.36 €	389.8
Group 4	5	14.7+17.8+14.8+15.4+11.4	74.1	1.3	439167.0	122,724.72 €	236.6
Group 6	3	19+19+19	57	1	196.0	93,671.63 €	234.8
Group 7	4	17+22+19+13	71	1.2	295.0	105,000.00 €	211.3
Group 8	3	26,43+20,21+25	71.64	1.35	529.3	128,788.25 €	256.8
Group 9	5	13,2+14,86+18,9+18,86+9,12	74.94	1.1	246.0	166,322.13 €	317.1
Group 10	5	14.34+14+19+19+22.4	88.74	1.27	363.9	158,169.02 €	254.6
Group 11	4	18,75+18,75+18,75+18,75	75	1.3	300.0	87,267.00 €	166.2
Group 13	4	19+22+19+21	81	1.5	89.0	188,754.88 €	332.9
Group 14	3	20+27+27	74	1.35	409.8	150,584.00 €	290.7
Group 15	4	15+22,5+22,5+8	68	1.5	425.2	112,617.30 €	236.6
Group 16	4	19+19+19+19	76	1.4	316.0	100,494.17 €	188.9
Group 17	4	21,5+20+20+12	73.5	1.2	486.4	127,959.00 €	248.7
Group 18	5	7,7+16,14+19,6+19,9+13,28	76.62	1.2		86,873.24 €	162.0
Group 19	5	13,5+15+19+19+9,5	76	1.25	368.0	99,656.00 €	187.3

Figure 5. Comparison of results published in Twitter (year 2016/17)

In addition to the development of the project, active methodologies were introduced in the classroom to increase the student's interest in the field of study. Classroom activities, such as tests after or during the master classes, were introduced to improve learning from a more active perspective.

From year 2018/19, a total of 13 2-hour sessions were planned for workshops, that is 26 hours/60 hours of class (15 weeks; 30 × 2-hours sessions), which represented more than the 5 sessions developed in the first edition of the 2016/17 academic year. For non-face-to-face activities outside the classroom, a 44-hour dedication was planned. The remaining 46 hours of dedication outside the classroom were recommended to dedicate a part to the study of the subject (20 hours) and the rest (26 hours) to the development of the coursework and the elaboration of the final report and the final presentation. Table 1 shows the organization of the 13 workshops, the corresponding session of the workshop in relation to the 30 2-hour sessions of the course, their objectives, deliveries and the partial formative assessment.

Workshop	Session	Objective	Delivery	Assessment
W#1	#2 (week 1)	Construction site visit or seminar by a professional of a construction company	Establishment of 10 rules for group work following the instructions and guide for setting rules given to students	
W#2	#5 (week 3)	Conceptual design of a structure with a design engineer. Aspects that should be considered in the definition of a structure. Identification of problems, external contour conditions	Conceptual design map	Feedback about the contour conditions will be given through the virtual campus
W#3	#6 (week 3)	Geometric definition of the structure	Drawings of the geometry of the structure: plan view, elevation, section	
W#4	#8 (week 4)	Presentation of the geometric solution. Loading definition according to existing codes. Calculation of the envelopes of forces using commercial software		Formative assessment about the type of the section and the dimensions
W#5	#12 (week 6)	Calculation of the envelopes of forces using commercial software	Submission of envelopes of forces at ULS and SLS	Formative assessment of the envelopes of forces
W#6	#14 (week 7)	ULS of bending with or without axial forces. Design of the longitudinal reinforcement in the horizontal and vertical elements	Submission of the schematic drawings of the longitudinal reinforcement of the most unfavorable sections and a justification of the analysis	Formative assessment of the longitudinal reinforcement ratio (order of magnitude will be checked)
W#7	#16 (week 8)	ULS of shear. Design of the transverse reinforcement in the horizontal and vertical elements	Submission of the transverse reinforcement for the most unfavorable sections and a justification of the analysis	Formative assessment of the transverse reinforcement ratio (order of magnitude will be checked)
W#8	#18 (week 9)	Longitudinal distribution of the reinforcement obtained in the previous W#5 and W#6, and calculation of anchorage and overlapping		Formative assessment about the longitudinal distribution during the workshop
W#9	#20 (week 10)	Definition of the reinforcement detailing	Drawings of the longitudinal and transverse reinforcement	Formative assessment of the final reinforcement distribution

Workshop	Session	Objective	Delivery	Assessment
W#10	#22 (week 11)	Assessment of the SLS of cracking for the deck in the most unfavorable section	Update of the longitudinal reinforcement distribution after SLS verification	
W#11	#23 (week 12)	Assessment of the SLS of deformability		Formative assessment about the SLS verifications.
W#12	#24 (week 12)	Bill of quantities considering volume of concrete, reinforcement ratios and formworks		
W#13	#25 (week 13)	Final presentation. Twitter activity to analyze the project results	Presentation/Twitter publication	Summative assessment

Table 1. Workshop organization, objectives, deliveries and assessment

2.2. Measurement Tools

2.2.1. Collection of Evidence of the PBL Implementation Through the Grades

The grade of the exams, the grade of the project coursework and the final grade of the subject were used as a comparison tool between the years before and after the application of PBL.

The final grade (F) was obtained considering the partial exams (E), the coursework (C) and the active learning activities (P). For the last editions (2018/19, 2019/20, 2020/21, 2021/22), the percentages of each concept in the final grade were the following: $F = 0.50 \cdot E + 0.40 \cdot C + 0.10 \cdot P$. The grade of the exams (E) was obtained from the two partial exams (P1 in week 6 and P2 in week 15) ($E = 0.40 \cdot P1 + 0.60 \cdot P2$). The grade of the coursework C was obtained from the final submission and the final presentation given during the last lecture day. Students had a rubric in the virtual campus for the oral presentation assessment. For the 2016/17 academic year, the final grade was obtained as $F = 0.60 \cdot E + 0.40 \cdot C$, since the active learning activities were not considered in the summative assessment. Finally, before the implementation of PBL, the final grade F was $F= 0.70 \cdot E + 0.30 \cdot C$.

2.2.2. SEEQ Survey

The Student Evaluation of Educational Quality (SEEQ) survey (see Annex 1) was conducted for the students of the Reinforced Concrete subject during the years 2016/17, 2018/19 and 2021/22. This survey was answered on paper in editions 2016/17 and 2018/19, and through a Google Form in 2021/22, at the end of one of the last lectures and results were processed using an Excel sheet. The number of participants were 36 students out of 55 (65.5%) for the year 2016/17, 19 out of 31 (61.3%) for the year 2018/19, and 20 out of 24 (83.3%) for the year 2021/22. The percentage of participants was slightly higher than 60%, so results can be considered to be representative. Table 2 describes the most important design aspects of the survey. During the editions 2019/20 and 2020/21, the survey was not conducted due to the pandemic situation. The SEEQ survey is an instrument for the formative assessment introduced by Marsh (Marsh, 1982). The data collected is used to improve the process (formative assessment) and accredit its quality (summative assessment) (Andrade-Abarca, Ramón-Jaramillo & Loaiza-Aguirre, 2018). The SEEQ survey provides information on nine different aspects of teaching: learning, enthusiasm, organization, interaction with the group, individual rapport, breadth, workload/difficulty, exams and assignments. Data collected serves to improve the strategies implemented in the applied methodology (Andrade-Abarca et al., 2018; Grammatikopoulos, Linardakis, Gregoriadis & Oikonomidis, 2015; Martín, Arias-Masa, Traver-Becerra, Contreras-Vas & Cubo-Delgado, 2017; Mohd.Majzub, Yusuf & Tamuri, 2010). Answers are in a range between 1 to 5. Individual answers in addition to the nine aspects have been analyzed through the mean value (MV), coefficient of variation (CV) or by assessing the percentage of answers in each range.

Survey	Description
Type of survey	Transversal
Population	Students of RC subject of 2016/17, 2018/19 and 2021/22 academic years
Confidence interval	95 %
Sampling error	0.02 %
Survey period	November 2017 for 2016/17 academic year May 2019 for 2018/19 academic year May 2022 for 2021/22 academic year
Sample	55 students (answers 36, 65.5 %) for the 2016/17 academic year 31 students (answers 19, 61.3 %) for the 2018/19 academic year 24 students (answers 20, 83.3 %) for the 2021/22 academic year Voluntary non-probabilistic
Process	Anonymous face-to-face
Data collection instruments	Paper in 2016/17 and 2017/18 Google Form in 2021/22
Data analysis instruments	Microsoft Excel®

Table 2. Most important design aspects of the survey

2.2.3. Student Interviews

In addition, interviews were conducted to a group of students that took the Reinforced Concrete subject during the 2016/17 or 2018/19 academic years. The first interviews were conducted to 14 students (25% of the total number of students in the group) during the month of November 2017, a few months after the end of the 2016/17 academic year. Then, the perspective of students was more distant than from when they were taking the course. The second group of interviews were conducted to 12 students (39% of the total number) just after finishing the 2018/19 academic year. In 2020/21, the opinions of the students where gathered in an open question added to the SEEQ survey answered by 11 students (55% of the total), since it was not possible to have interviews face-to-face due to the pandemic situation.

To ensure representativeness, a random sampling method has been used in the selection of participants. Each individual in the target population has a known and non-zero probability of being selected to participate in the interview. This random sampling increases the chances of obtaining a sample that is representative of the population as a whole. The sample size guarantees representativeness and is sufficiently large to capture the variability and diversity of the population. The population size, desired level of confidence, and acceptable margin of error have been taken into account.

The purpose of the interviews was to get information complementary to that obtained with the surveys, that is, the impact of the project methodology in their learning, in their knowledge, in the acquisition of competences, their degree of satisfaction, how did students value the approach to real problems with the coursework. Finally, the opinions gathered were used to enhance future editions of the course.

3. Results of the PBL Implementation

3.1. Results from the Grades

Table 3 shows the results in terms of percentage of passing students, mean value (MV) of the final grade and coefficient of variation (CV) for the Reinforced Concrete subject, before (2015/16) and after implementing PBL (2016/17, 2018/19, 2019/20, 2020/21 and 2021/22).

As observed in Table 3, better results in terms of final grades have been obtained after applying PBL. In the year 2015/16, the percentage of passing students was 55%, and it increases up to 96% during 2021/22. In addition, the mean value for the final mark has increased from 4.7 to 7.2 in the last years. The mean value of the final mark is quite similar for the year 2016/17 and for the years after introducing PBL. It should be mentioned that in 2016/17 we started introducing PBL but with less activities than in the last editions. The coefficient of variation of the final grade has decreased from 28 to 15-19%, except in the last edition when it raised up to 23%.

Year	PBL	#	% Passing students	MV Exams	CV Exams	MV Coursework	CV Coursework	MV Final grade	CV Final grade
2015/16		70	55%	2.3	80.3%	5.2	68.7%	4.7	28.0%
2016/17	X	55	89%	5.3	34.1%	7.8	21.2%	6.9	15.5%
2018/19	X	31	84%	5.1	40.8%	7.9	12.4%	6.9	15.5%
2019/20*	X	35	95%	6.6	23.0%	8.1	14.0%	7.2	17.2%
2020/21*	X	20	85%	6.1	30.1%	7.8	23.8%	7.1	19.0%
2021/22	X	24	96%	6.0	36.1%	7.8	20.9%	7.0	23.6%

*Pandemic context

Table 3. Percentage of passing students, mean value (MV) and coefficient of variation (CV) of the grades before and after implementing PBL in the Reinforced Concrete subject

In relation to the mean value of the grades of the exams, it has increased from 2.3 to 6.6. It should be mentioned that the grades of the exams corresponded to the value of the partial exams, considering a weight of 40% for the first partial exam and 60% for the second one. The grade of the coursework has also increased after applying the PBL methodology.

3.2. Results from the SEEQ Survey

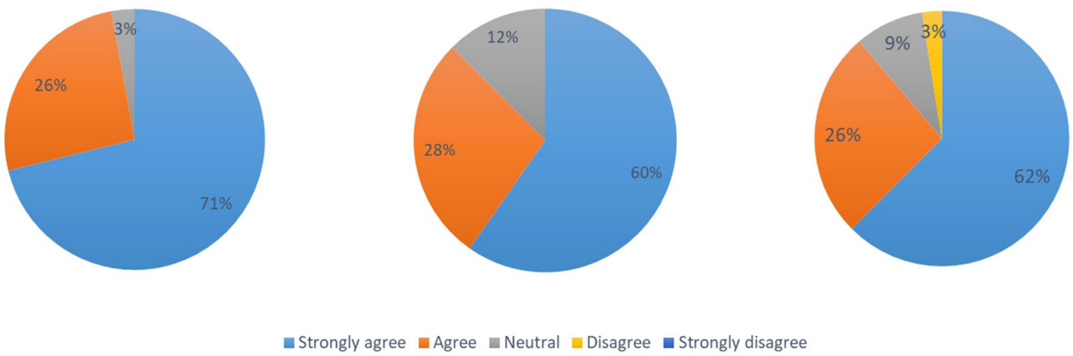
The Student Evaluation of Educational Quality (SEEQ) survey was used to collect the assessment of teaching in the 2016/17, 2018/19 and 2021/22 academic years.

Figure 6 shows the results of questions related to learning. As observed, nobody strongly disagreed with the four questions of this block. In relation to the first two questions, which asked if the course is intellectually challenging and stimulating and if they have learned something valuable, students strongly agreed (90.4% year 2016/17, 77.8% year 2018/19 and 66.5% year 2021/22) or agreed (9.6% year 2016/17; 16.7% year 2018/19 and 32.5% year 2021/22) in all of them. Considering all editions, 50-60% of students strongly agreed and 20-37.5% agreed with the statement that the interest in the subject had increased as a consequence of this course. Finally, the last question of this group "I have learned and understood the subject materials of this course", it is remarkable that 7.6% (2016/17) and around 20% (2018/19 and 2021/22) of students were neutral with this question. Although teachers were asking more often to students if they were understanding all the concepts since 2018/19, one student of the year 2021/22 answered that he/she has not learnt and understood the subject materials of this course.

In relation to the questions related to the organization of the course (Figure 7), the mean results of the four questions have slightly improved from the first edition of PBL to the second one. From the respondents, 93% of students (year 2016/17), 97% (year 2018/19) and 94% (year 2021/22) strongly agreed or agreed with the proper organization of the course. Moreover, 83% (year 2016/17), 96% (year 2018/19) of students strongly agreed about the question "The Instructor's explanations were clear". For year 2021/22, the percentage of students that strongly agree decreases to 70% but 25% of students agreed with this statement. From this section, the question where the percentage of the "agree" answer increases in relation to the remaining questions, is the last one: "Instructor gave lectures that facilitated taking notes".

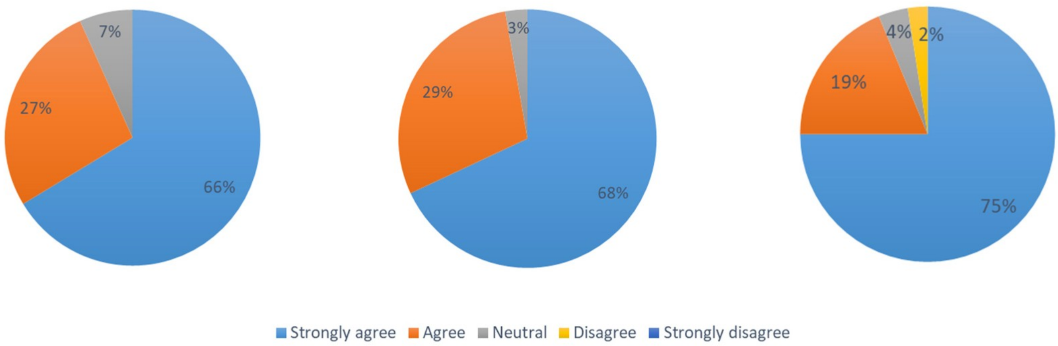
Figure 8 shows the results related to the exams. As observed, in all cases around 95% of students strongly agreed and agreed with the questions related to the feedback given by the teacher about exams and homework; about the assessment methods, if they were fair and appropriate; and about the correspondence between exams and the course content. In addition, it is remarkable that the mean value for the question related to the appropriateness of exams had increased from 4.31 to 4.78 from the course of the first PBL implementation to the second edition, and had flatten out till 2021/22.

Figure 9 shows the results related to assignments. In the 2018/19 academic year, a small percentage (5.6%) of students disagreed with the statement: "References, homework, laboratories contributed to appreciation and understanding of subject".



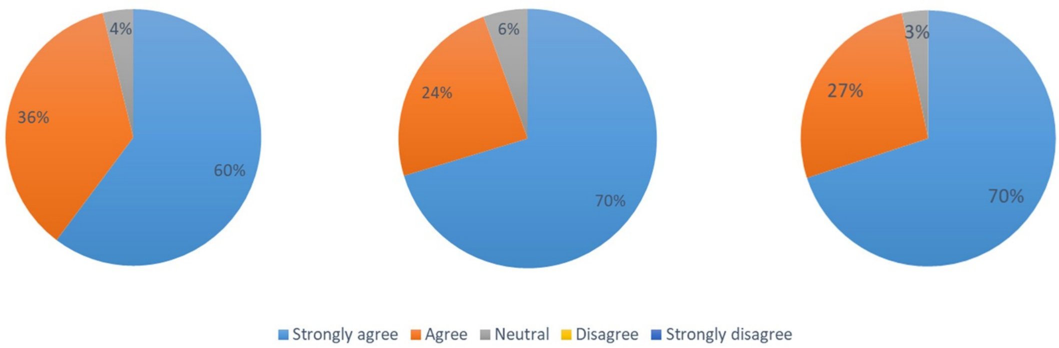
a) 2016/17 b) 2018/19 c) 2021/22

Figure 6. Results related to questions about learning for the SEEQ surveys



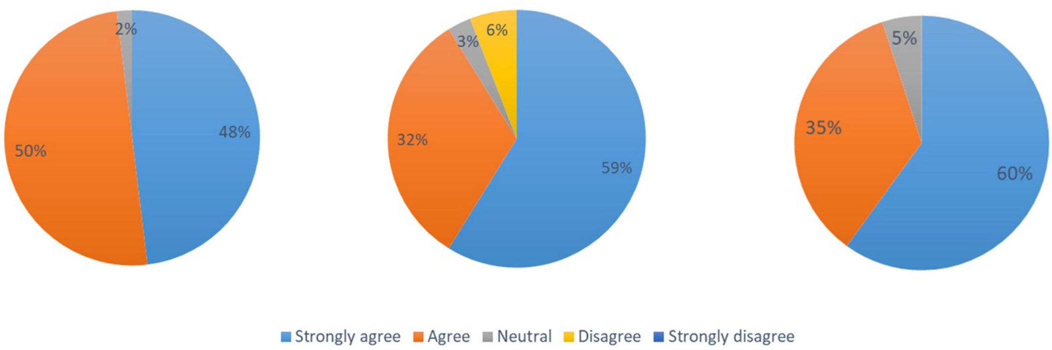
a) 2016/17 b) 2018/19 c) 2021/22

Figure 7. Results related to questions about organization for the SEEQ surveys



a) 2016/17 b) 2018/19 c) 2021/22

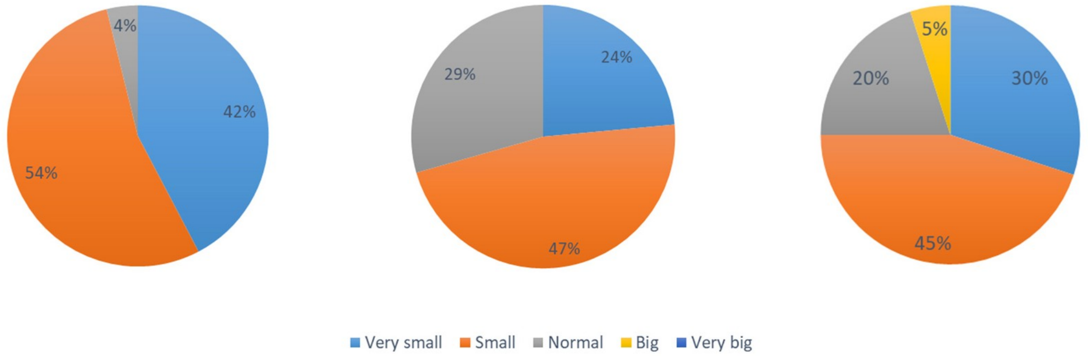
Figure 8. Results related to questions about exams for the SEEQ surveys



a) 2016/17 b) 2018/19 c) 2021/22

Figure 9. Results related to questions about assignments for the SEEQ surveys

Finally, regarding “the workload of this course compared to other subjects of the same year” (Figure 10), 96% of students of year 2016/17 thought that the workload and difficulty was very small or small. However, this percentage had decreased to 71% in the second edition of PBL and to 75% for year 2021/22. From the respondents, 29% for year 2018/19 and 20% for year 2021/22 thought the course workload was normal compared to other courses. In 2018/19, regarding the question about weekly hours dedicated to the subject, 38% answered that the hours they dedicated to it were between 5 and 7 hours per week and 38% between 8 and 12 hours per week, and only 13% dedicated more than 12 hours per week. However, in 2021/22, students devoted less time to the subject (30% less than 2 hours per week, 35% between 5 and 7 hours per week, only 5% between 8 and 12 hours per week and nobody more than 12 hours).



a) 2016/17 b) 2018/19 c) 2021/22

Figure 10. Results related to questions about workload and difficulty for the SEEQ surveys

3.3. Results from the Student Interviews

According to the interviews conducted to some groups of students (section 2.2.3), some advantages of the current methodology and some drawbacks or aspects were identified and some improvements were introduced in the last and in the current editions.

The perception after the first interviews (14 students, year 2016/17) were the following:

- In general, students valued learning through a course project very much. They believed that applying theory to a practical case is the best way to learn.
- In general, they highly valued that it is a project of a real case, and that it begins with the conceptual design of the solution, that is to say, when thinking about the solution from the beginning from the external conditioning, trying to justify the reason to be. This last point was very important for students because they have never done it.
- Students asked for more continuous follow-up among the workshops conducted, as in some cases, students worked and progressed during the days before the workshops and the same day of the workshop, but afterwards, they left the coursework aside until the next workshop.
- Students have understood that they need to prepare all data required in the workshop because if not it was difficult to get back to work and catch up.
- Some students commented that they prefer to leave work at the end, and organize on their own. It should be mentioned that these students did not usually attend all classes, but attended from time to time.

In order to reduce the inconveniences mentioned by the students, the number of workshops during the course was increased in the following editions after year 2016/17. The schedule and objectives of each workshop were announced in advance, as well as the starting data they are going to need for its proper development.

The perception after the interviews of year 2018/19 (12 students) were the following:

- Students pointed out that this was the first time during the degree that they dealt with a real structural engineering problem. They thought that this will be helpful for their real professional life.
- Students agreed that the course was well organized and thanks to this organization, they knew how to advance in the project during the workshops.
- Students commented that classes were dynamic and that the participation was encouraged. Participation was significantly higher in comparison to other courses. Students knew that it was really important to contribute to increase the knowledge of the class group. It does not matter if their contribution was wrong, since they also learned when they made a mistake.
- Students found very useful all the workshops organized for the project development and they appreciated the instantaneous feedback because they were able to check if they were progressing in an appropriate manner.
- Students thought that the content of the course was really extensive and that it should be shortened.
- Finally, students considered that they have improved their teamwork and communication skills.

The perception given by the open comments of the survey of year 2021/22 (11 students) were similar to the ones given in the previous interviews. Only few new comments were added:

- Students valued the adjustments performed in the subject due to the pandemic situation.
- Students valued the implication of the professor and the availability for answering questions.
- The work load is very high, but the structure of the subject allows to learn a lot in a short period of time.

Through these interviews, it has been observed an increase in their satisfaction degree after introducing PBL. However, we should continue implementing improvements in this subject, maybe by selecting the most important topics and suppressing the less relevant ones.

4. Discussion of the PBL Implementation

After the implementation of the PBL in the RC subject, the two research questions of section 1.6 were properly answered:

1. Students improved their learning because, they acquired and retained the knowledge related to the objectives of the subject. This was observed in the performance of students that took the optional Prestressed Concrete subject the semester after the RC subject, for the academic years with PBL. In addition, students had acquired the generic, specific and transversal competences corresponding to this subject. In particular, students had learned to work in groups, had acquired leadership skills, had learned to defend ideas, had improved their critical spirit as in (Kwan, 2016), and finally had learned time management and had improved their oral communication, which is consistent with other existing studies such as (Gavin, 2011; Quinn & Albano, 2008). It has been also observed that students had increased their entrepreneurship skills. As mentioned in (Coronado, 2003), Spanish engineering graduates have good abstract knowledge, they are very submissive and have poor entrepreneurial capabilities and this might have a relationship with the classical learning environment. These skills improved thanks to PBL. Students also developed effective management strategies during discussions and disagreements related to knowledge between the group (Murray, Hendry & McQuade, 2020).

2. It was observed an improvement on the assessment of the RC subject. Table 3 has shown the evolution of the grades on the Reinforced Concrete subject after applying PBL in comparison with a previous edition with traditional teaching (year 2015/16). As observed, the percentage of passing students increased from 55 to 95% by applying PBL methodology. The mean value of the final grade also increased from 4.7 to 7.0-7.2 and the coefficient of variation was significantly reduced, which shows less dispersion in the final grades. Nowadays, the high percentage of students who pass the subject is due to the continuous work that should be developed during and after the workshops of the coursework and thanks to the formative assessment given during them. The increase in the grade of the coursework could be explained by the fact that students dedicated more time to this coursework, since they worked in the classroom and at home, and then their learning and knowledge about the subject increased, and this was reflected on the summative assessment. In addition, the coefficient of variation of both the exams and the coursework has significantly decreased in the last years after introducing PBL. This means that the grades were more homogeneous in the whole class group.

Due to the PBL implementation, some additional consequences on the students' performance were observed:

- Students learned to think as engineers, as also observed by (Murray et al., 2020), knowing that the solutions to problems are not unique and they try to develop the most optimal one, and define it with all the details so that at the end, it can be built.
- Students learned orders of magnitude and learned to know if the calculations they made are consistent or meaningless.
- Most of the students have not studied only for the partial exam and have forgotten all the knowledge the day after.
- Students' motivation increased, arising their interest in structural engineering, as also observed in (De Justo & Delgado, 2015) and (Silva, Sabbatini & De Barros, 2012). This can be partially attributed to the development a project similar to professional practice.
- More students were interested in developing their bachelor thesis in a structural engineering topic.

The change towards a more active way of learning implies an important effort for the faculty, since all the planning and organization of the classes must be modified. A revision of the syllabus was made, shortening some topics or preparing additional documentation to be learned by the student's own account. In addition, it was necessary to think about possible actions to keep students up to date and to avoid a possible and undesirable abandonment caused by the introduction of the proposed change. This time input required was one of the main drawbacks of this methodology in accordance with the conclusions of (Gavin, 2011; De Camargo-Ribeiro & Mizukami, 2005; Chinowsky et al., 2006; Johnson, 1999; Steinemann, 2003).

The results of the SEEQ survey corroborate the findings of some other similar experiences such as (Silva et al., 2012). A high percentage of students considered that the course was challenging and stimulating and that they learned something valuable. Students did not complain about exams and assignments, since they thought that they were appropriate and related to the contents developed in the course.

In general students strongly agreed or agreed with the organization of the course. Despite that the explanations of the lecturer were clear according to students' opinion, some of them (6% for the 2016/17 year, 11% for the 2018/19 year, and 5% for the 2021/22 year) were neutral and did not agree with the statement that the lecturer facilitate taking notes. These results could be related with some of the comments given by the students during the interviews conducted, where some of the students had the perception that the speed of the master lectures was very fast. Students recommended to spend more time in these sessions. However, the total time of the course was limited, and if we dedicated more time to master lectures then we had to sacrifice the number of workshops that were very useful for them. This aspect has been improved during the edition 2020/21, by uploading some short videos in the virtual campus. Some of them were prepared due to the pandemic situation in 2019/20.

The assessment methods were fair and appropriate for the students and they are related to the contents of the course. As observed in the survey, the mark related to this question improved from the first (4.31) to the second edition of PBL (4.78) and held steady up to the last edition. The difficulty of the exams is similar for all academic years, but the coursework helped the students to understand all the different concepts that are asked later on in the exam.

In relation to the questions about the coursework, it was observed that a small percentage (5.6%) of students of the year 2018/19 thought that the coursework did not contribute to the appreciation and understanding of the subject. This might be explained by the fact that the survey was conducted the same day of the coursework presentation, and this fact might have influenced their answer, since if they did not work properly during the coursework, they might have worked many hours before the coursework submission and presentation. In addition, this perception was not observed in year 2021/22.

On the contrary of that expressed by (Gavin, 2011), students thought that the workload and difficulty was small or similar to other subjects of the Bachelor. In this case, it seems that it was more time demanding for faculty than for students. It is remarkable the decrease in hours dedicated to the course, from year 2018/19 to 2021/22. This aspect will be monitored in the following editions, since this might be due to the change in the Studies Plan implemented in year 2019/20. All students of the group of year 2021/22 were students adapted from the old curriculum. Therefore, some of them might have a worse performance along the bachelor degree than in previous student groups.

In relation to the results of the nine aspects analysed by the SEEQ survey, the general perception of the course has improved along the different editions, as observed by the percentage of "strongly agreement" or "agreement" with the different statements. However, in year 2021/22 a small percentage of disagreement appeared in the questions related to learning, organization and workload.

Interviews performed to students corroborate the direct results mentioned in this section about improvement of learning and skills. In addition, these interviews were useful for improving the content and organization of the course.

Finally, as also observed by (Murray et al., 2020), team-based activities linked to PBL offered students a quasiauthentic experience of engineering practice, which was really appreciated.

5. Conclusions

This section summarizes the conclusions drawn from the implementation of PBL in the Reinforced Concrete subject of the Bachelor in Civil Engineering of the [University]. This paper applies PBL in a reinforced concrete design course in civil engineering education and provide insights into its effectiveness in enhancing student learning outcomes, attitudes, and skills.

PBL is a teaching methodology that emphasizes the development of students' critical thinking, problem-solving, and communication skills through hands-on, real-world projects. This approach has been shown to be effective in engaging students, enhancing their learning outcomes, and preparing them for professional practice. Thanks to the coursework, students have learned to design a real reinforced concrete structure from its conception, following the same procedure that a professional due in daily engineering practice. This coursework has been developed in a continuous manner along the semester thanks to the class workshops. Students have appreciated the continuous feedback given by the teacher during the workshops. The continuous and formative assessment has been easier by applying the PBL methodology.

According to the results obtained by the research performed, students were more motivated, and they increased their learning and their knowledge about the subject. This was reflected in the improvement of the final grades of the subjects in comparison to those obtained by students before applying this methodology. Students did not perceive that they had an overload of work in comparison with other subjects with the PBL implementation.

Continuous improvements were implemented along the three editions of the subject with PBL such as the introduction of more workshops and office hours to address all possible problems during the project development, or the development of audiovisual pills as a complement to the master classes to address some important aspects that might not have been properly assimilated during the lectures.

The following editions of the Reinforced Concrete course will be a challenge, since due to the change in the curriculum of the Bachelor in Civil Engineering, the number of students will increase up to 80-100 students per year in three different groups with different professors. In the near future, one of the aspects we want to work on is considering the coursework to be a project challenge presented by a company. In this case, the company might have a certain interaction with the students. A couple of workshops or activities with the company can be designed at least at the beginning and the end of the project. The end activity will be to present their final product. In addition, an activity related to the Sustainable Development Goals will be designed and implemented in the coursework.

Finally, students' feedback was really important for the improvement in the teaching activities. Therefore, in the following years the SEEQ survey will be particularized by adding some specific questions related to the PBL, and results will also be compared with the current editions. Interviews that were interrupted in year 2019/20, will resume again in the current edition of the course. In addition, we will continue having an open question in the survey SEEQ, since students might prefer to give anonymous comments in some cases.

Acknowledgments

The authors would like to thank all the students who took part in answering the surveys and the interviews.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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Annex 1. SEEQ Survey

Please evaluate your experience in this class using the following scale: **(1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree**	**1**	**2**	**3**	**4**	**5**
Learning:					
1. I have found the course intellectually challenging and stimulating.					
2. I have learned something which I consider valuable.					
3. My interest in the subject has increased as a consequence of this course.					
4. I have learned and understood the subject materials of this course.					
Enthusiasm:					
5. Instructor was enthusiastic about teaching the course					
6. Instructor was dynamic and energetic in conducting the course					
7. Instructor managed to make his presentations enjoyable					
8. Instructor's style of presentation held my interest during class					
Organization:					
9. Instructor's explanations were clear.					
10. Course materials were well prepared and carefully explained.					
11. Proposed objectives agreed with those actually taught so I knew where course was going.					
12. Instructor gave lectures that facilitated taking notes.					
Group Interaction:					
13. Students were encouraged to participate in class discussions.					
14. Students were invited to share their ideas and knowledge.					
15. Students were encouraged to ask questions and were given meaningful answers.					
16. Students were encouraged to express their own ideas and/or question the instructor.					
Individual Rapport:					
17. Instructor was friendly towards individual students.					
18. Instructor made students feel welcome in seeking help/advice in or outside of class.					
19. Instructor had a genuine interest in individual students.					
20. Instructor was adequately accessible to students during office hours or after class.					
Breadth:					
21. Instructor contrasted the implications of various theories.					
22. Instructor presented the background or origin of ideas/concepts developed in class.					
23. Instructor presented points of view other than his/her own when appropriate.					
24. Instructor adequately discussed current developments in the field.					
Examinations:					
25. Feedback on examinations/graded materials was valuable.					
26. Methods of evaluating student work were fair and appropriate.					
27. Examinations/graded materials tested course content as emphasized by the instructor.					
Assignments:					
28. Required references/texts were valuable.					
29. References, homework, laboratories contributed to appreciation and understanding of subject					

Please evaluate your experience in this class using the following scale: **(1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree**	**1**	**2**	**3**	**4**	**5**
Please evaluate your experience in this class using the following scale: (1) Very poor, (2) Poor, (3) Average, (4) Good, (5) Very good	1	2	3	4	5
Student and Course Characteristics:					
30. Course difficulty, relative to other courses, was: Please evaluate using the following scale: (1) Very easy, (2) Easy, (3) Average, (4) Difficult, (5) Very difficult, N/A					
31. Course workload, relative to other courses was: Please evaluate using the following scale: (1) Very light, (2) Light, (3) Average, (4) Heavy, (5) Very heavy, N/A					
32. Course pace was: Please evaluate using the following scale: (1) Too slow, (2) Slow, (3) About right, (4) Fast, (5) Too fast, N/A					
33. Hours/week required outside of class: Please evaluate using the following scale: (1) 0 to 2, (2) 2 to 5, (3) 6 to 7, (4) 8 to 12, (5) More than 12					
Overall: (N/A, Very Poor, Poor, Average, Good, Very Good)					
34. Compared with other courses I have had at the University, I would say this course is:					
35. Compared with other instructors I have had at the University, I would say this instructor is:					
Other opinions about the subject and the course:					
36. Level of interest in the subject prior to this course was: Please evaluate using the following scale: (1) Very low, (2) Low, (3) Medium, (4) High, (5) Very high, N/A					
37. Expected grade in the course: Please evaluate using the following scale: (1) Less than 3.0, (2) 3.0 to 4.9, (3) 5.0 to 6.9, (4) 7.0 to 8.9, (5) more or equal to 9.0					
Comments/Feedback (for year 2021/22): Please provide any additional comments or feedback:					

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Journal of Technology and Science Education, 2024 (www.jotse.org)