PBL from Real Projects and Students Initiative: a case study

MARIO SOLÍS and ANTONIO ROMERO

E.T.S. Ingeniería, Universidad de Sevilla, Camino de los Descubrimientos s/n, 41092, Sevilla, Spain
E-mail: msolis@us.es; aro@us.es

Abstract

The benefits of Project Based Learning (PBL) to acquire technological knowledge as well as transversal skills by students are well known. However, the implementation of PBL requires additional efforts from teachers and students, as well as additional teaching resources when compared to traditional teaching. This paper presents a case study of a singular PBL experience developed within a subject entitled Experimental Structural Analysis. This subject had PBL already implemented. However, the paper describes a new PBL experience that was suggested by some students that were part of the Formula Student (FS) team from the University of Seville. 24 students and 2 teachers took part in this new experience. The proposed PBL introduced some new challenges in the subject. The paper describes how the subject was organized in terms of theoretical and practical lessons, tutorials and assessment (including the introduction of a novel Self Assessment Factor). The paper analyzes the results from an academic point of view and describes the benefits, difficulties, advantages and opportunities arising from a PBL approach in which students play a new role as real promoters of a real project. Results from academic scores, surveys from students and teachers' perceptions are analyzed. The percentage of students who ask the teachers of the subject to supervise their final degree project is used as a new satisfaction indicator from students. The paper shows that this PBL methodolodogy is enriching and suitable for the learning process of most the students. However, new challenges arise such as encouraging all the students to be actually involved in the cooperative work and ensuring that the main theoretical concepts are learned. The FS competition is proven to be a good opportunity for implementing PBL based on a real project.

Keywords: PBL; Formula Student; real project; self assessment

1. Introduction

PBL is based on the constructivism learning approach, which suggests that human being construct his/her knowledge on experience and his/her efforts to give meaning and understand that experience, connecting to prior knowledge. In PBL, finding a solution to a practical problem is the way not only to acquire new knowledge related to a specific subject but also to acquire additional skills such as a cooperative work, self-criticism, written and oral communication, etc. A brief and clear description of constructivism principles and their relationship with PBL can be found in [1].

The roots of PBL come from the 1930s [2] and it was implemented in 1969 in McMaster University in Canada [3]. Originally, it was developed for medicine studies [3-4]. Since then, it has been successfully applied to other disciplines. Nevertheless, each discipline has its own singularities, and PBL must be suitably adapted to be included within the program of any academic subject or syllabus [3, 5]. The main difficulty when introducing PBL in engineering is the complexity of many basic concepts that are required to address any realistic and complex problem (the so-called threshold concepts as defined by [6]). These concepts in engineering are related mainly to physics and mathematics, but also each engineering discipline has its own related threshold-concepts. For instance, the concept of internal forces and stresses for structural engineering.

Teaching these basic threshold concepts require the use of a directive traditional teaching, which may be therefore the most suitable teaching methodology during the first years of an engineering degree syllabus. PBL may be progressively implemented course by course so in the last year almost every subject could use it as a teaching methodology. The experience of the Architecture Faculties of Newcastle (Australia) and Delf (Holland) illustrates how this hierarchical structure of knowledge can be taken into account [7]. However, there are also some experiences of implementation of PBL throughout the whole degree syllabus, although a progressive project complexity is considered for an adequate learning process [8].

There has been successful experiences of PBL in structural analysis and design reported by many authors (see for instance [9]). In these examples, structural design is taught through solving a practical problem, while traditional teaching is mostly devoted to structural analysis rather than structural design. The latter is indeed a much more complex skill, which is usually acquired during professional experience and it is difficult to teach with traditional methodologies.

This paper presents an application of PBL in a suitable academic context. The subject (named Experimental Structural Analysis) corresponds to the last course or a five-year undergraduate syllabus, so all the basic concepts of engineering and also the more specific knowledge of structural engineering have been already learned. On the other hand, the number of students is small enough (usually between 10 and 20). The content of the subject is devoted to experimental work, and the students must learn how to perform experimental tests in the lab, so the tests are not used for illustrating any theoretical structural analysis concept, as it usually happens in other subjects, but to learn how to deal with data acquisition systems, sensors, data analysis, etc. In this context, PBL emerges as a natural way of teaching and learning: practical problems (tests) must be solved (design, setting-up, analysis of results), real tests are performed and small groups of students are required to allow them to take part in the tests. Previous knowledge is required to understand the test, to process the experimental data and to analyze the results.

The implementation of PBL in this subject has been already reported by the authors [9-10]. It was a pioneering experience of PBL approach in the Higher Technical School of Engineering of the University of Seville, since it was introduced before the new European Higher Education Area (EHEA) was established. The EHEA promotes this teaching methodology and because of that the number of innovative teaching methodologies experiences, including PBL, is increasing since the EHEA implementation in the University of Seville [11] and more specifically in its Engineering School [12].

This paper will present the results of a new experience within the Experimental Structural Analysis subject. During the 2013-2014 academic year, a group of the students of the Engineering School decided to create a team to take part in the international Formula Student competition, an international competition of racing cars for undergraduate students. Some of those students were also involved in the Experimental Structural Analysis subject and asked the teachers for help in the experimental tests required for the structural design of the frame of the racing car. These tests were finally carried out within the subject applying a PBL approach.

There are some technical papers related to the design of Formula Student racing cars [13-16], but the authors are only aware of the use of the Formula Student Competition as a PBL approach in the FH Joanneum University of Applied Sciences in Austria [17].

This paper describes the use of this type of real project carried out by the students as the motivation for PBL in the University of Seville. The paper is organized as follows. Firstly, the context of the experience is described. For that purpose, the Formula Student competition is presented in order to describe the implications of the overall project and more specifically the technical implications that were addressed in the course. After that, the academic context of the experience is described, including how it was originally promoted by students and how the course was organized in order to cover the technical aspects of the real project as well as the academic goals of the course. Finally, the results of the experience are analyzed, including data from the scores of the students as well as the perception from students and teachers.

2. The Formula Student competition

This competition was originally promoted in 1981 by the Society of Automotive Engineers (SAE) in the USA. From 1998, the Institution of Mechanical Engineers and SAE have been holding the annual European Formula Student Competition. It is a well established event that excites and encourages young people to take up a career in engineering. Undergraduate students from universities of all around the world are organized by themselves into teams that take part in the FS competition. The competition makes students to conceive, design, build, present and compete as a team with a small single-seat racing car in a series of static and dynamic tests. It provides an ideal opportunity for the students to demonstrate and improve their capabilities to deliver a complex and integrated product in the demanding environment of a motorsport competition. The competition is not a usual car race. The overall results are based on an evaluation of the whole project of the students. The score of each team does not depend only on the vehicle performance from a technical point of view, but also on the design process, the manufacturing process and also the business plan.

The different disciplines that the teams must passed are described next. They are divided into static (the car is not operating) and dynamic (car operating) disciplines.

Static disciplines:

- Engineering design: each team elaborates a Design Report describing their constructive solutions. At the competition, the judges examine the constructions and discuss them with the students.
- Cost and manufacturing: the judges analyze a written report from the students and discuss with them about the manufacturing process and costs
- Business: each team present a business plan for their prototype to assumed manufacturers and sponsors

Dynamic disciplines:

- Acceleration: the vehicle must follow a line of 75 meters in the shortest time
- Skid-pad: the vehicle is driven in a circuit in a 8 shape in order to show its lateral acceleration capacity
- Autocross: the driving dynamics and handling qualities of the vehicle are measured from a course of one kilometer through straights and curves
- Endurance: The vehicles have to prove their capabilities (acceleration, speed, handling, fuel economy, reliability) over a distance of 22 kilometers around a demanding circuit.

In the summer of 2013, a group of the students from the School of Engineering of the University of Seville decided to create a team to take part for the first time in the international Formula Student Spain competition in 2014. The Formula Student Spain is one of the Formula Student events that take place every year around the world. It is organized since 2010 in the Montmeló circuit (Barcelona) and the number of participants is increasing year after year. There were 12 participants in 2010, 22 in 2011, 30 in 2012, 34 in 2013 and 50 in 2014. Since 2012, the cars are divided into combustion and electric cars categories. In 2014 there were 26 combustion cars and 24 electric cars coming from different countries (26 from Germany, 11 from Spain, 3 from Italy, 2 from Belgium, 3 from United Kingdom and 1 from Russia, Romania, India, Portugal and Czech Republic).

The new team from the University of Seville was named the ARUS team [18] . Along the 2013-2104 academic year they had to face the design and manufacturing of their first prototype of the car from the very beginning. It was

definitely a very demanding and challenging task. The team was formed by 60 undergraduate engineering students and they were organized in 9 divisions: team leaders, secretary, aerodynamics-exterior bodywork, chassis, cockpit, suspension-steering-brakes-wheels, motor-auxiliary-transmission-electronics, management, and marketing.
The whole FS project could be addressed through many different subjects within the Mechanical Engineering Syllabus where PBL could be used as a teaching methodology. This could be achieved by following the progressive complexity PBL implementation proposed in REF Capart2013. The multidisciplinary approach of the FS project and its large complexity make it not possible to be addressed in a single subject. This paper describes how only part of the structural design was finally included in the Experimental Structural Analysis Subject.

3. Traditional organization of the subject

The Experimental Structural Analysis is a 4.5 European Credit Transfer and Accumulation System (ECTS) credit subject. Each ECTS credit corresponds to 10 hours of classroom teaching (theoretical or practical) and 15 hours that the student should work on his/her own. The main contents and academic goals of the subject are:

- Basics of instrumentation (data acquisition systems, errors, etc)
- Sensors and experimental techniques in mechanical engineering
- Use of strain gages
- Experimental Dynamic Structural Analysis (Modal Analysis)

Since the establishment of the subject in 2002, a set of practical lessons have been designed for addressing those contents from a practical point of view and following a PBL approach [9]. In addition, the practical lessons also trained some transversal skills such as analysis and interpretation of real experimental data, communication, report writing, team working, etc.
The practical lessons changed from one year to another, according to teachers curiosity, ongoing research projects, students suggestions, etc.
The 45 hours of classroom teaching were divided into 15 hours of theoretical teaching and 30 hours of practical lessons. In the theoretical lessons, the background of the contents of the subject were explained. The threshold concepts related to this specific subject were taught during this theoretical lessons. A total of 12 practical lessons (1,5 hours each) were carried out along the semester, illustrating the theoretical concepts and giving the students the opportunity to work on their own as much as possible. They were involved in the experimental set up and in the acquisition of the signals from sensors. They were also in charge of processing the experimental data and draw conclusions from the experimental tests, making use of their background on mechanical engineering and structural analysis. The practical lessons were carried out in small groups (4-6 students) and smaller groups (2-3 students) were in charge of preparing a written report and an oral presentation about the work of each lesson. The total number of students for this subject was usually between 8 and 20.
The final score in the subject was obtained from a theoretical exam of 1h of duration (30% of final score), and the work from the practical lessons (70% of the final score). The final score also included a weighting factor based on a self-assessment system where each student proposed a grade for themselves and also for their classmates.
Thus, following this teaching methodology, a PBL approach was established, but each project (each practical lesson) had a short time to be developed and it was previously defined and limited by the teachers guidelines. The results of this teaching approach were very satisfactory, as reported by the authors [9-10], despite the increase in their teaching load.

4. New organization of the subject

During the first semester of the 2013-2014 academic year, a group of students ask the teachers of the subject for assistance in the structural design of the new chassis for their FS racing car, since the students already knew the teachers from previous Structural Analysis subjects. The teachers were gratefully involved in the project as technical advisors. As part of the design process, the students asked about the possibility of performing real experimental tests on their new chassis, so they could confirm the performance of the new structure and ensure its safety. Moreover, these tests could serve as a valuable result to be considered by the judges of the FS competition when the project was presented.

Some of the students that asked for these tests were also students of the Experimental Structural Analysis subject that is taught during the second semester. Thus, the teachers suggested that the proposed experimental tests could be included as part of the subject. However, they warned the students about the new challenges and additional working load of carrying out the proposed tests. The teachers would have to make a big effort to deal with a new organization of the subject, but on the other hand they asked the students to be involved and to be committed to taking part in the development of the subject and the experimental tests.

The inclusion of the FS Team requirements for the experimental tests made the subject to be reorganized. That was a big challenge for the teachers. The contents of the subject had to be covered and the academic goals had to be accomplished through new experimental tests, a new scope, and a new role for the students. Moreover, in that academic year, the number of the students in the subject was 24 (relatively large if compared to previous years).

As a result, the subject was organized as follows. The contents of the theoretical lessons were kept in the same way as in previous years, since the main theoretical contents of the subject did not change. However, the practical lessons and the organization into groups was significantly changed. The number of experimental tests was reduced, but on the other hand the students had to be more deeply involved in the experimental set-up and also in the analysis of the results. The students were divided into 4 groups of 6 students, and each group was in charge of a particular type of test and particular tasks. Moreover, the work from all the groups were related to each other so they had to work in coordination not only with the colleagues from their group but also with the rest of the class.

Two teachers were in charge of the subject. Each one was responsible of teaching half of the theoretical concepts and was also responsible of the work of two of the student groups.

4.1 Subdivision into groups of students

The division into four groups was as follows:

Group 1: Static load tests for the mechanical characterization of the bars of the structure . This group was in charge on preparing some bars for performing tensile tests and four point bending tests. The ultimate strength, elastic modulus, yield stress, local buckling resistance to point loads and bending resistance were valuable data for the proper design of the chassis of the racing car. Different types of bars that were considered for the construction of the structure were tested in order to select the most suitable and to check their performance. This group was in charge of preparing the devices for fixing the bars to the testing machines, review the standards for each test, decide where to put strain gages on the bars, etc.

Group 2: Static test of the structure. This group was in charge of designing a couple of tests to measure the torsional and bending stiffness of the whole structure . The positions of displacement sensors, strain gages as well as the way of fixing the structure to a reaction frame were planned by this group. The torsional and bending stiffness of the structure are important parameters in the design process of a racing car since it affects its performance and safety.

Group 3: Dynamic test of the structure . This group was in charge of identifying the natural frequencies and mode shapes of the structure. The tests consisted of several experimental modal analysis by applying an input force with an impact hammer. This feature was considered to be important by the FS team in order to avoid resonance phenomena. This group had to decide where to install the accelerometers and where to excite the structure. Several positions were considered and the results were compared and analyzed. When setting up the test, they had to deal with the definition of important parameters for a dynamic test, such as the sampling frequency, time of measurement, rejecting/accepting impacts, way of averaging, etc. They had also to design the supporting conditions of the chassis and the dead loads to be added to the structure in order to simulate as close as possible the real situation of the chassis when the car was completely built.

Group 4: Numerical analysis. This group used the numerical model developed by the FS team for the design of the chassis . Actually, some of the students of this group had previously worked on this model as part of the FS team, so the model was familiar to them. This group performed several static and dynamic simulations of the static and dynamic tests, in order to provide useful preliminary information for the tests, such as critical positions for installing the sensors, range of expected magnitudes to be measured, etc. In order to obtain realistic values, they used the properties for the bars that were determined from the tests conducted by group 1. Thus, the numerical analysis group was in a very close dependency with the rest of the groups. They did not perform any test by themselves but at the same time they had to be familiar with all the tests that were carried out.

4.2 Practical lessons

During the course, the practical lessons were organized as follows. Each group had a 2.5 hours of practical lessons each week, so the total amount of practical lessons was the same as in previous years, but their work was organized in a different way. Half of the practical lessons (half of the weeks) were dedicated to design, prepare and set up the experimental tests, and the rest of the practical lessons (the rest of the weeks) were dedicated to perform the tests. Each group was responsible for preparing one type of test and also of showing the rest of the groups how the test had been designed, the type of experimental information to be collected and the expected results. Thus, each group was responsible of "teaching" the practical lessons related to the tests they were in charge of. On the other hand, all the groups eventually took part and learned from all the tests. As a consequence, the learning experience was shared by all the students.

Besides the tests conducted by the students, there were also some practical lessons conducted by the teachers that were focused on illustrating some fundamental theoretical concepts. Those lessons covered the following topics:

- Installation of strain gages and measuring strains in a structure
- Design of an instrumentation system for a specific test (the students have to look in the internet for suitable products such as data acquisition system, sensors, software, etc.).
- Identification of natural frequencies and mode shapes of a structure

At the end of the year, each group prepared a written report about their tests and they presented their results to the rest of the class, including some time for discussion.

5. Assessment methodology

The score for each student was obtained from the assessment of his/her contribution to the experimental work, written report, oral presentation, discussions, explanations to other groups, etc. This score was a 70% of the total grade of the subject. The written exam (30% of the total grade) was kept in order to ensure that the theoretical concepts had been learned and also to check how the students had learned from the tests from other groups (some questions or exercises were included about each test). The written exam serves as a tool to modulateKK the grade obtained by each student since the assessment of the individuals is a major challenge when applying PBL in groups of students [19,20].

The final score of each student was finally weighted by a novel normalized factor (Self Assessment Factor, SAF) obtained from a self assessment procedure. The SAF was obtained from the score that each student proposed for the students of his/her group (including him/herself) and for the students of the rest of the class. Assuming that the students had a more clear perception of the work carried out by the people from their group, a 75% of the SAF value was obtained from the self assessment from students from the same group and 25% from the rest of the students. The scores are in a range from 0 to 10 points, but the SAF is obtained from the weighted averaged and normalized value. Thus, a student with a SAF value higher than 1 will increase the grade proposed by the teachers, since the classmates considered he/she has done a better job than the average. A value lower than 1 has the opposite effect for the opposite reason.

The proposed application of the SAF is in between a basic self-assessment method and a more sophisticated and detailed peer assessment method [21]. The normalization of the SAF and its use as a coefficient affecting the assessment from teachers reduce the effect of discrepancies usually observed between the scores assigned by teachers and students [19].

The mathematical definition of the SAF for each student can be written as

$$SAF=\frac{1}{10}\cdot\left[0{,}75\cdot\left(\frac{\sum_{i=1}^{N_G} S_i^G}{N_G}\right)+0{,}25\cdot\left(\frac{\sum_{j=1}^{N_{OG}} S_j^{OG}}{N_{OG}}\right)\right] \quad (1)$$

where N^G is the number of students in the same group of the student , S_i^G is the score assigned by each colleague of that group, including the student by himself/herself, N^{OG} is the number of students in other groups, and S_j^{OG} is the score assigned by those students. The factor 1/10 is included in order to normalize the SAF to unity, since the students use the usual range in Spain from 0 to 10 points to assign their scores (S_i^G and) S_j^{OG}.

6. Discussion of academic results

Following this PBL approach, the students learned the main concepts about experimental structural analysis, which is the main goal of the subject. They learned this concepts from a theoretical point of view but also from their application to real tests. Transversal skills such as written and oral communication, team work, cooperative learning, etc., were also trained within the subject.

From an academic point of view, the achievements were similar to previous academic years with a different PBL approach.

6.1 Academic Scores

The academic scores from the students were similar to previous academic years, although slightly lower values were obtained. Fig. 1 (a) shows that there is a lack of high global scores and most of them are in the low-medium range (5-7 points). The reason for this is mainly the worst results from the written test (Fig. 1 (b)), since the scores from the practical lessons are similar to previous years (Fig. 1(c)).

The SAF was generally in the range 0.9-1.1, so the grade proposed by the authors was usually increased or decreased by a 10% (Fig. 2). However, one student obtained a low SAF (0.77). The teachers also considered that this student deserved a low score because his reduced contribution to the team work of his group and the low quality of his job. However, since the practical work is developed by the whole group, it is not easy for the teacher to propose an impartial and not subjective score for this type of “passive” students. This is a major dificulty when work is deveoloped in groups [19,20]. Thus, the SAF is a useful tool to correct the grade of the students considering the opinion of the classmates, who have a more direct perception of the actual contribution of each student.

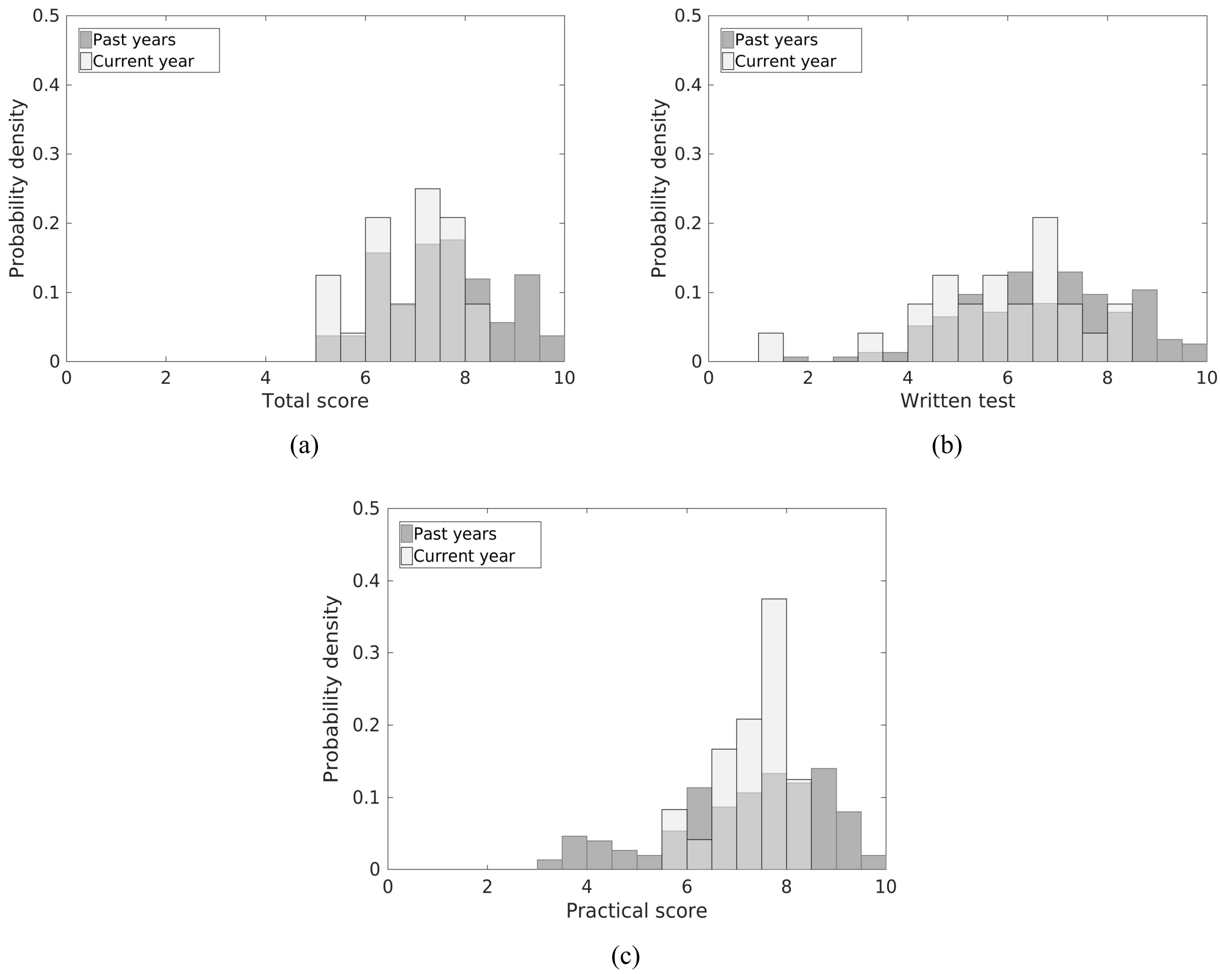

Fig. 1: Normalized distribution of the scores from students from previous years and the current year (with the Formula Student PBL approach): (a) global scores (b) scores from written test (c) scores from practical lessons

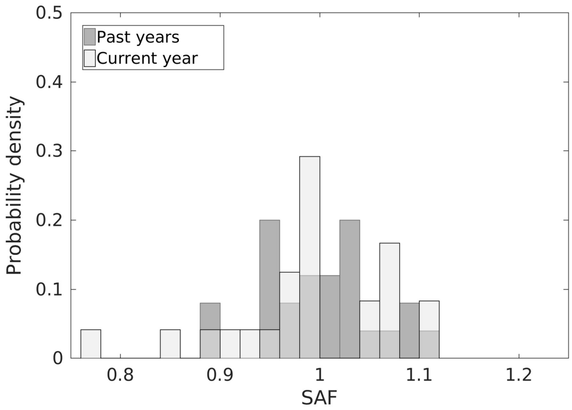

Fig. 2: Normalized distribution of SAF factor from students from previous years and the current year (with the Formula Student PBL approach)

It was also amazing that the student that made the biggest effort for developing this PBL approach because of his leadership in the FS student team, obtained also a relatively low SAF (0,85). The teachers believe that his leadership was not totally accepted by the students or that he did not succeed in communicating with some of the students. As a conclusion, the SAF may help the teachers and also the students to have a broader perspective of the quality of the work done by each student, considering not only academic or technical knowledge but also social abilities, which must be also part of the education at university level. This fact has been also been observed by other authors [19].

6.2 Students' perception (surveys)

Each year, at the end of the course, the students are asked to fill out a survey where several aspects from the subject are assessed from 0 (worst) to 10 (best) points. The items included in the surveys were:

- Q1- Interest of contents and objectives of the subject
- Q2 -Organization of the subject (practical/ theoretical lessons)
- Q3- Classes enjoyment
- Q4- Assessment methodology and criteria
- Q5- Clarity and quality of teachers explanations
- Q6- Overall evaluation of the teacher
- Q7- Overall evaluation of the subject

Fig. 3 summarizes the results from the surveys of previous years and from the Formula Student PBL approach year. Traditionally, the students appreciate this type of subject where there are not many difficult concepts but they learn, review and put into practice many valuable ideas from structural analysis, mechanical engineering, electrical engineering, experimental analysis, etc. They also appreciate the PBL teaching methodology, as well as the training in transversal skills, as it has been also reported in [22].

However, the new PBL approach based on the FS project did not make the students to show a better perception of the subject, according to the assessment registered for each item .

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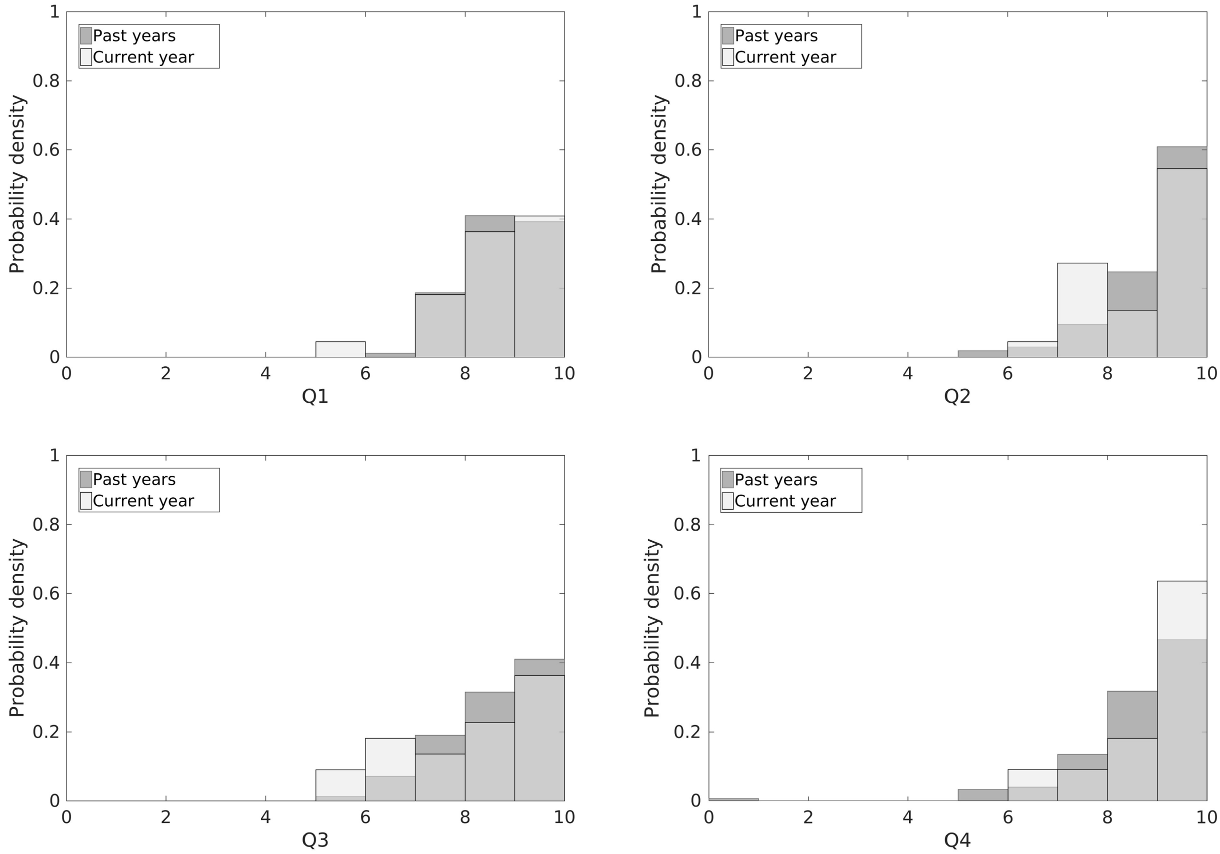
The perception from students is very similar to previous years, but a better perception was registered about the assessment methodology (Q4) and also from the teachers and the subject (Q6, Q7). This result may indicate that students enjoyed the subject because of their involvement on its organization and development. It also may indicate that students appreciated the attitude, sensitivity and commitment from teachers to the learning process of students [22].

This paper presents a novel indicator of the satisfaction from students that also supports the previous statement. This indicator is based on the amount of students that ask the teachers at the end of the course to be the advisors of their final degree project. This project is the final work that students have to do before being acknowledged as professional engineers. It usually consists of a practical work related to the ongoing research activity of teachers or to any professional engineering project. When looking for an advisor of the final project, students usually ask teachers they have valued their way of teaching, attitude, etc. Fig. 4 shows the number of students of the subject for each academic year along with the number of students whose final degree project was conducted by the teachers of the subject. It can be observed that the highest proportion of conducted final degree projects took place when the number of students is small (years 2004 and 2011) and also when the FS PBL approach was carried out (year 2014). This result shows that when the number of students is small, it is easier to establish a closer relationship with students and therefore to encourage them to work in the subject and other academic activities. However, this can be also achieved if a proper teaching methodology is applied, even though the number of students is high. This happened in year 2014, meaning that the FS PBL approach encouraged the students in their learning process and made them have a better perception from teachers. Actually, the average percentage of students whose final degree project was supervised by teachers of the subject was 8%, whereas during the FS PBL approach this percentage raised to 24%.



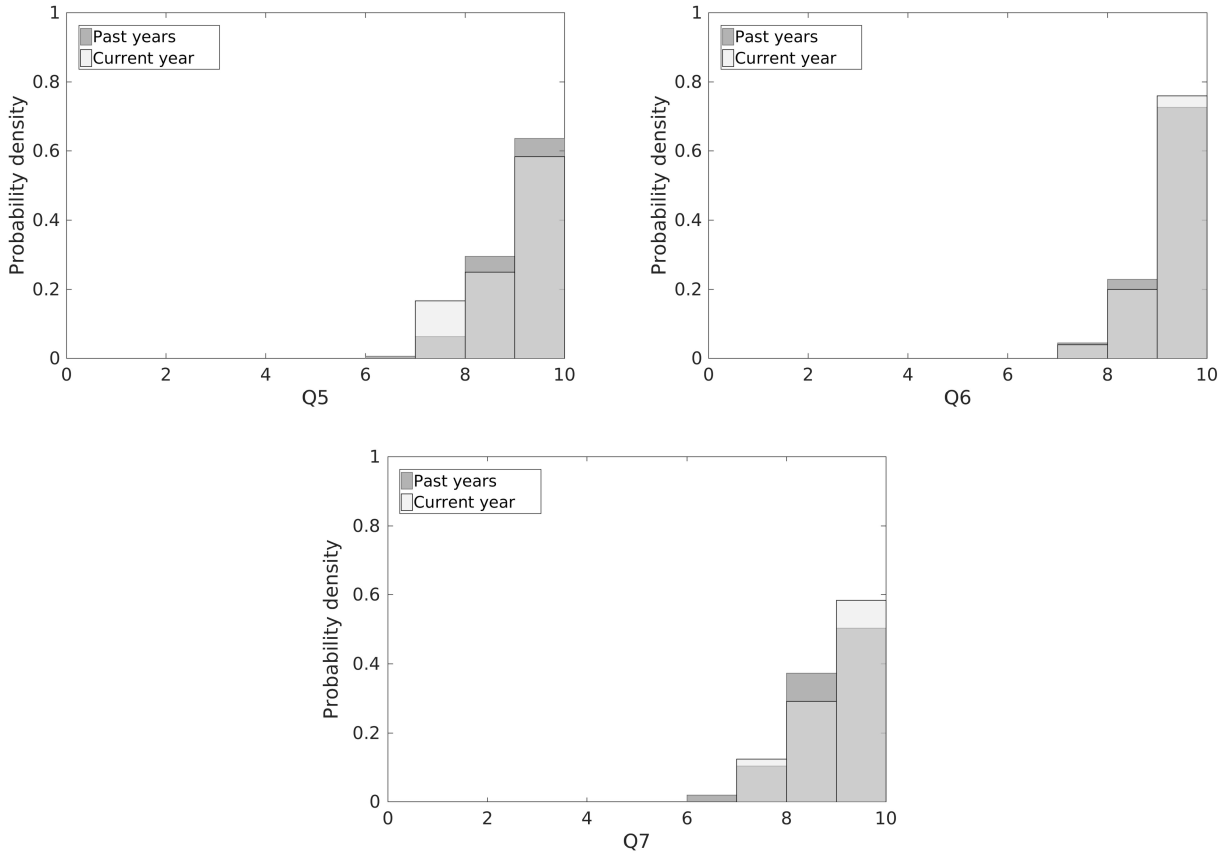


Fig. 3: Normalized distribution of the evaluation from students for the 7 items of surveys (Q1 to Q7) from previous years and the Formula Student PBL approach year

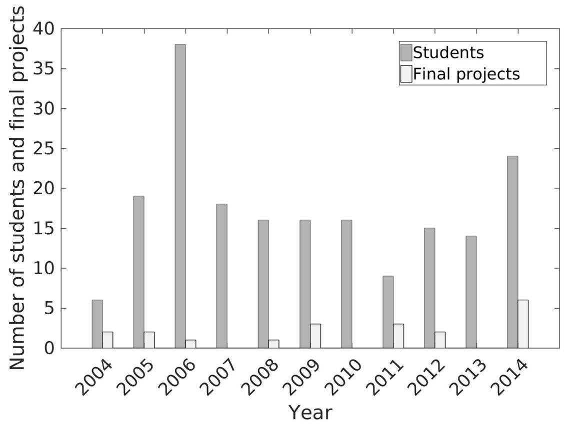


Fig. 4: Number of students of each academic year and percentage that their final degree project was conducted by the teachers of the subject

6.3 Teachers' perception

The implementation of this new PBL experience required a significant increase in the teaching load. The design of the new experimental tests and the new organization scheme of the subject, together with the coordination with the students and also with the FS team was a big challenge. However, the teachers are glad to see that students can directly participate in the developments of the contents of a subject, following their interests and their motivation. They feel this experience is enriching for the students as well as for the teachers. However, they believe that part of the class was strongly motivated by this experience (mainly the students that were part of the FS team and those that were friends of them and were aware of the achievements of the FS team), whereas other part of the class did not feel comfortable with the idea of being somehow following the leadership of some of their classmates or were not interested in the FS experience. Moreover, some students could feel disappointed because the organization of the subject was complex and it could be confusing for them at some points. Because of these reasons, the surveys from the students do not clearly reflect a better perception about the subject than previous years. Some students had a better perception of the subject but some others had a worst one. Similar conclusions have been drawn in previous works [22].

One of the main difficulties in succeeding with the implementation of this type of experience in this subject is to ensure that the academic contents are covered and learned by the students. They are more involved in some practical aspects of the experimental tests, in the organization of the subject and in the real FS project, but at the same time they pay less attention to the general theoretical concepts and they only get familiar to those concepts related to the work of their corresponding group. This is shown by the fact that the results from the written exam were worse than previous years (Fig. 1(b)). In order to improve this situation, the communication between the different groups should be more fluent, and the teachers should make sure that all the students take part in all tests and they learn from all of them.

Moreover, the number of the students should be smaller in order to make it easier to organize the groups and the tests, and also to allow teachers to encourage students and thoroughly supervise the work of all .them

7. Conclusions

This paper presents a successful implementation of a PBL approach based on a real project proposed by the students. The results shown from this experience shows that this type of experience can be very enriching, but at the same time some difficulties are encountered. When the motivation of the students is high, they can learn new concepts more easily and effectively, according to the constructivism approach. However, some students prefer to receive a more classical teaching, they do not like to feel responsible for their learning process and their motivation for taking part in this type of learning approach can be low. Encouraging those students or planning alternative ways of learning the subject for them can be also a time consuming and difficult task for teachers.

Moreover, when following this PBL approach, the teachers have to think of academic tools to check and to ensure that the theoretical concepts are learned. A written exam may be a good tool for that purpose. Actually, the results from the written exam showed that the main theoretical concepts were worse acquired than in previous years.

Regarding the assessment, the proposed normalized weighted Self Assessment Factor has proven to be a good tool for modulating the results obtained by the individual members of each working group.

The FS project has shown to be a good opportunity for implementing PBL in many subjects of engineering education. Taking part in this competition is an ideal framework for implementing PBL using a real project that strongly motivates the students. However, because of the complexity of the overall team project, it is only feasible to address just one little part of it in any course of the degree program. Moreover, the supervision of this type of lively project, in which the students take the initiative and define their own work poses new challenges to teachers. Despite these difficulties, the authors encourage faculties, teachers and students to be involved in these type of projects and combine a real world engineering project with the academic activity.

Acknowledgments

This work was supported by the Consejería de Economía, Innovación, Ciencia y Empleo of Andalucía (Spain) under project P12-TEP-2546. The financial support is gratefully acknowledged.

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Mario Solís Muñiz (Mechanical Engineer, PhD) works as an Assistant Professor at the Continuum Mechanics and Structural Analysis Department of the University of Sevilla (Spain). His research work has covered the development of numerical models for fracture mechanics of smart materials, damage detection and Structural Health Monitoring. Because of his involvement in International Cooperation Projects with NGOs and international research projects with Peruvian universities, his research has also addressed the structural behavior and seismic performance of low cost building materials. Because of his expertise in structural analysis, dynamics of structures and experimental testing, he has taken part in some relevant restoration projects of Cultural Heritage sites in Sevilla and Granada. He is an author of more than 80 research publications including papers in scientific journals, chapters of books and contributions to conference proceedings. Regarding his teaching experience, he has been in charge of several subjects related to structural analysis (bars, plates, static, dynamic, experimental techniques), steel structures and aerospace structures. He has conducted several innovative teaching experiences where PBL and the involvement of students have played an important role.

Antonio Romero Ordóñez (Mechanical Engineer, PhD) is an accredited Researcher in Continuum Mechanics and Theory of Structures at University of Seville (http://orcid.org/0000-0002-8879-5535). PhD in Mechanical Engineering, associate Research at the Department of Continuum Mechanics and Theory of Structures, Universidad de Sevilla, within the Spanish National Science, Technology and Innovation grant program; has published 3 chapters in book, 16 papers in international scientific journals with referees and participated around 40 communications in conferences; has got a research fellowship at the Federal Institute for Material Research and Testing (2011 Berlin, Germany) and at the Institute for Research and Technological Development in Construction Sciences (2012 Coimbra, Portugal). His area of expertise is focused in numerical modelling and experimental analysis of soil-structure interaction problems and the study scattering waves on fluid and solid mediums. He has been awarded extraordinary prize for bachelor theses and extraordinary prize for PhD theses.

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