PBL to foster integration of company projects in engineering curricula – A case example

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PBL to foster integration of company projects in engineering curricula – A case example

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Abstract

New trends and demands on engineering workplace call for more generic and employable competences such as communication, teamwork skills, problem-solving skills, lifelong learning, and digital literacy. Engineering education institutions are pushed to change and integrate more student-centred learning methodologies in their curriculum, such as problem-based, project-organised learning (PBL). PBL enables engineering students to develop knowledge and competences aforementioned. Furthermore, PBL provides opportunities to increase and diversify the collaboration between universities and industry, fostering innovation. Industry case examples have been proved to increase student interest and motivation. However, this paper describes a step forward on that industry-university collaboration level: involving companies in the project based learning experience. That is, involving the company in the tutoring and evaluation of a project developed by different groups of students. This could be understood as a dual training format more adequate for intermediate levels of bachelor degrees, when students are not mature enough to do a job in a company and get paid for it. This paper describes the experience of the Faculty of Engineering, Gipuzkoa (University of the Basque Country UPV/EHU, Spain) in supporting PBL integration in curriculum and in building industry collaboration. This paper descries the strategy Faculty of Engineering, Gipuzkoa (University of the Basque Country UPV/EHU, Spain) implemented with aim to develop a more innovative engineering education by re-organising their courses around projects and in collaboration with companies. Furthermore, the faculty's strategy is compressive, meaning that includes different strategies giving the students different learning experiences and contact with work place and employers in different moments of their education.

Keywords: Academic staff training, PBL, company projects, dual training.

Type of contribution: PBL best practice

1 Introduction

There are many attempts to reduce the gap between university and business, it is desired that the university prepare students adequately for their profession and it is hoped that business will be part of the solution. To this end, opportunities must be created for companies to get involved and work collaboratively with teachers, being part of the process and contributing to the quality of student work.

Companies give great added value to the academic work when they help teachers to create real tasks and projects. When students work on problems that matter, they get involved and make the problem their own, achieving better results. The key to a good University-Business-PBL relationship is to create a benchmark of what the university/university tutor will need from the company/company tutor, while at the same time allowing the company to increase their degree of involvement if they wish so.

This article analyses the implementation of Projects in Collaboration with Companies (PCCs) in the Civil Engineering Degree at the Faculty of Engineering in Gipuzkoa (San Sebastian, Spain) during the 2018/19 and 2019/20 academic years. Ten teachers and 30 students participated in PCCs projects. The teachers received specific training in the field of PBL and industry involvement to support the implementation of these projects.

1.1 Problem based, project organised learning (PBL): the theoretical framework

Traditionally, Problem Based Learning (PBL) has been defined as a teaching environment where problems lead to learning (Woods, 1996). This methodology was first used at the Faculty of Medicine of the University of McMaster (Canada) in the early 1970s. Usually, the acronym PBL is also used for Project Based Learning, to emphasize the word project, which refers to "a problem of longer duration, with more facets and which allows for the broad and in-depth exploration of the problem posed" (Jorgensen and Howard, 2000).

Throughout the literature on engineering education, it is evident that PBL should be considered as an option to be studied in the development of new or in the modification of existing engineering programs (Johnson and Ulseth, 2016). The extensive experience of Aalborg University (Kolmos et al., 2004), pioneer in the systematic implementation of this teaching model, the UNESCO reports (UNESCO, 2010; Beanland and Hadgraft, 2013), or the studies of Graham (2012) or Mills and Treagust (2003), which identify the PBL as a key element in the design and implementation of more innovative engineering programs, clearly demonstrate it.

As defined by Thomas (2000), projects are "complex tasks based on challenging problems that involve students in design, problem solving, decision making or research activities, and that provide the opportunity for students to work relatively autonomously for extended periods of time to complete realistic products or presentations". It also establishes the five fundamental criteria that must be met in order to consider a methodology as PBL:

- Centrality. Projects are a fundamental part of the curriculum. That is, through them, students learn and apply fundamental concepts. They are not complementary exercises.

- They are problem-driven. The problem to be solved becomes the thread of the subject.

- Constructive research. The central activities of the project must be a difficulty and, to solve it, students must "build" new knowledge. Therefore, it is important to avoid the simple application of established recipes or solutions.

- Directed by the students. Projects should incorporate a good dose of student autonomy, freedom of choice and decision-making, unsupervised work and responsibility on the part of students. Although the teacher is always behind to support and guide the process, the leadership must be of the students.

- Realistic. Projects should convey a sense of reality to students, which makes them more involved and results better.

It seems natural, taking a further step, to add to these criteria a complementary one: collaboration with the company, which only reinforces the sense of reality of the project, giving a professional context to the academic work and reinforcing the motivation of the students by giving a justification to the need to acquire certain theoretical and practical knowledge.

Although some experiences already incorporate the collaboration with companies in the design and/or monitoring of teaching projects (Wang et al., 2012), there are no known experiences where such collaboration is part of the curriculum of the subjects. At Aalborg University (Denmark), the collaboration with companies is considered a key element of the project, being this collaboration included in their educational vision (Aalborg University, 2015):

"External organizations are familiar with the Aalborg model and cooperate actively with the University on students' Project work."

"The University's collaboration with external organizations contributes to ensuring that students are able to work with contemporary issues that are relevant to their discipline or profession."

In this context, with the objective of involving companies in student training, and with the limitations inherent in the structure of the Degrees involved, the Faculty of Engineering in Gipuzkoa proposes the Projects in Collaboration with Companies (PCCs).

1.2 Reducing the gap between University and Companies: the goal for engineering education at the Faculty of Engineering of Gipuzkoa

The Faculty of Engineering of Gipuzkoa located in San Sebastian (Spain) was founded in 1952 and was integrated into the recent public university, University of the Basque Country (UPV/EHU), in the 1970s. Today, the Faculty offers five B.Sc. degrees in Industrial Engineering (Mechanical, Electrical, Electronic, Renewable Energies and double degree Mechanical-Electronics), two B.Sc. degrees in Construction (Civil Engineering and Building Engineering) and four M.Sc. degrees.

Like many other higher education institutions, teaching methodologies have evolved greatly in recent decades, moving from a teacher-centred model to a more diverse and flexible student-centred model, with continuous evaluation and giving a major boost to teaching innovation. Specifically, with regard to the UPV/EHU's model of curricular development of teaching, it is based on the IKD Irakaskuntza Kooperatiboa eta Dinamikoa or Cooperative and Dynamic Teaching (www.ehu.eus/es/web/sae-helaz/ikd): a model that is unique, cooperative, multilingual and inclusive, and which emphasises that students should be the owners of their own learning and be trained in a comprehensive, flexible way that is adapted to the needs of society. The IKD model was unanimously approved by the UPV/EHU Governing Board in 2010 and developed in an operational manner in the Strategic Plan 2012-2017.

In addition, University-Business relations have been one of the priority axes of the UPV/EHU. Euskoiker, a non-profit organization, is a foundation, which has as its objective the development of relations between the UPV/EHU and society. Since 1979, it has managed numerous research projects, made strategic contacts and participated in several research presentation forums. As regards the Faculty of Engineering of Gipuzkoa, this University-Business relation is clearly reflected in the internships and the Bachelor Final Projects carried out in the industry. During the 2019-20 academic year 70% of the students did an internship in a company and more than 50% carried out their Final Project in companies, or external institutions.

This model is coherent with the priority axis University+Industry defined by the University Plan of the Basque Government 2019-2022. Likewise, the UPV/EHU makes this objective its own, establishing the following axis of action in the Strategic Plan 2018-21:

"To promote learning in real professional contexts through dual training in undergraduate and postgraduate studies, and the carrying out of internships, Bachelor final projects, Mater theses and doctoral theses in collaboration with the public administration, companies and social entities".

With all this, the Faculty of Engineering of Gipuzkoa has recently committed itself to an educational model based on university and industry collaboration. This model promotes the acquisition of skills by students, involves the industry in the training of students and brings the university closer to the reality of the professional and social worlds.

The educational model includes two different strategies to involve the companies in the engineering programmes and students' learning: training in the company and training in collaboration with the company. The first strategy refers to an internship in the company, which is the most common one employed in engineering education. However, this strategy has some disadvantages when is considered for intermediate courses of scientific-technical qualifications, i.e. courses that compose the curriculum and students take along their education. For this reason, the second strategy, collaboration with the company, is developed and it is what the Faculty of Engineering of Gipuzkoa calls Project in Collaboration with Companies (PCC).

The PCCs arise as an answer to the question: How can universities offer engineering students work place learning experiences throughout their education and in collaboration with companies? The PCC methodology is an adaptation of the Project based learning (PBL) methodology in which companies participate in the design, development and evaluation of the project. Their implementation requires redesigning various courses, which would integrate one or several projects and in which the company collaborates. The company role takes special emphasis in certain key moments of the project development, which are fundamental for strengthening the process of acquiring disciplinary knowledge and developing skills.

2 Design, implementation and evaluation of PCCs in Civil Engineering

Today the Degree in Civil Engineering is taught in more than 25 Faculties in Spain, most of which are going through a difficult time to attract students. The crisis in construction of 2008, the successive changes in denominations of the Degrees and the expansion of the offer in technological degrees have had a strong impact on enrolment. The Civil Engineering Faculties in Spain are joining forces to make their offer more attractive, to disseminate the profession of the civil engineer, as well as to promote the visibility and knowledge that society has about Civil Engineering. This is confirmed by the latest conference of directors of Civil Engineering Faculties where the need to work on some of the following has been highlighted:

- To enhance the visibility and knowledge that society has about Civil Engineering
- Strengthening the university-business relationship
- Increase the versatility of civil engineers through multidisciplinary profiles
- To promote the figure of the Civil Engineer in work fields such as BIM methodology, Sustainable Cities, Circular Economy, Energy Efficiency, Smart Cities data management, climate change mitigation, etc.
- Disseminate the qualifications and the profession in order to awaken new vocations

Given the aforementioned, the Faculty of Engineering in Gipuzkoa considered appropriate to pilot the PCCs model in Civil Engineering degrees, whereas it can address some of aspects highlighted namely

strengthening university-business relationships. Design, implementation and evaluation constitute the main three phases of the pilot process of PCCs in civil engineering.

2.1 Designing of PCCs for the Civil Engineeringcurricula

The Degree in Civil Engineering at the Faculty of Engineering in Gipuzkoa runs for 4 years and has 240 ECTS credits. These credits are divided into 66 basic training credits, 144 compulsory (72 common to the civil branch, 48 of specialty or specific technology and 24 of complementary subjects), 18 optional and 12 of Bachelor Final Project. The proposal of the Faculty of Engineering of Gipuzkoa establishes that the 30 credits that are given in the last semester of the degree (optional credits and Bachelor Final Project) are carried out in a company (internship in company, see table 1). Some students are already doing this in a self-managed way. It is therefore a matter of facilitating the process and clarifying the procedure.

However, the main novelty comes from the PCCs. These projects will be offered in 2nd, 3rd and 4th year courses, increasing their presence as the students move up the year. In 2nd year, students start with one course, in 3rd year they take PCCs in two courses and finally in 4th year they take PCCs in 4 courses. In total PCCs shall be implemented in 42ECTS (7 courses of 6 ECTS each).

Table 1: Distribution of ECTS given with industry collaboration and mechanism (Internship or PCC).

Modules	Total ECTS	ECTS with industry	Strategy
Training	66	0	-
Civil Branch Specific Technology Complementary	144	42 (29%)	PCC
Optional	18	18 (100%)	Internship
Bachelor Final Project	12	12 (100%)	

In the PCC methodology, the academic tutor (AT, university professor responsible for the subject) and the tutor in the company (CT, person in the company who collaborates in teaching the group of students) define a problem or project to be solved that becomes the thread of the subject. The problem must be realistic, adapted to the level of the course but sufficiently complex to allow all the teaching activities of the subject to be articulated around it.

The role of the CT is fundamental to guarantee the direct and updated contact with the professional reality. On the other hand, this way of working is based on a relationship of trust and fluidity between the two people responsible for teaching, the AT and the CT.

The process of adapting from a traditional teacher-centred methodology to a project-based, student-centred methodology involves analysing the content or the time spent (hours spent in and out of class) by the students. In addition, when there is a third party, the company, this adaptation requires a careful analysis of the role of the company tutor, the key moments in their collaboration or the way in which they interact with the students, among other factors.

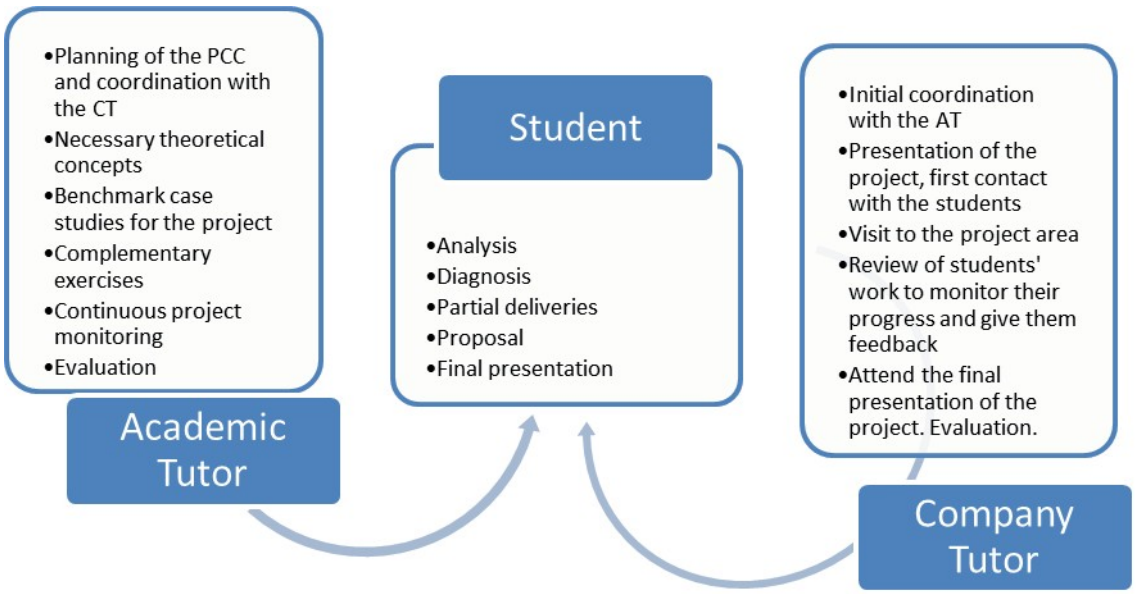


Figure 1: Participation scheme of the three PCC actors: academic tutor, student and company tutor. Source: Garmendia, Peñalba & Ostolaza (2019)

The first step is the choice of a typical project, which fits well with the subject and the skills that students must develop throughout the course. This is the key element for the success of the course. Ideally, from the point of view of student involvement and continuity, the course should be structured around a single project (although there may be several if necessary), thus making the project the main thread of the course. The project, having to solve this project (competence), is the reason why students must acquire certain knowledge. The project must be agreed with the company, so that the CT is clear about the skills and learning outcomes that students must acquire as a result of the project. Also, the AT can listen to what type of work the company partner does and problems that arise in that work, and together develop a driving question or statement for the project.

In addition, it is necessary to carefully design the programme of activities throughout the term. It should clearly establish the weekly tasks and activities of teachers and students, identifying deadlines, corrections, feedback, etc. Later, the development of the different activities and depending on the progress or difficulties encountered, this planning can be modified. In general, all PCCs follow the traditional structure in the elaboration of any project:

- Information, analysis and diagnosis.
- Proposal, comparison and choice of alternatives.
- Project development
- Conclusions

Depending on the location of the subject in the curriculum and the specific case, some phases may be more relevant than others. Thus, for example, in the second year projects, the first ones faced by the students, more emphasis is placed on the first two without having too much impact on the development of the final project; while in the third and even more so in the fourth year projects, the technical aspects of the development of the project are much more important, although this does not mean that the analysis and selection of alternatives are neglected.

Throughout a course based on the PCC, the class hours are dedicated to all kinds of activities of various kinds:

- Theoretical explanations by the responsible teachers or by the CT. They can be about some technical aspect needed for the project, about some instrumental aspect (representation, structure of documents, etc.), about some similar case to the project or about some general aspect of interest, even if it is not directly related to the project's subject.

- Workshop sessions in which the project is elaborated, the students' work is reviewed, it is discussed among students and/or with the teachers, etc. In these classes, teamwork is common.

- Scheduled revisions/corrections of the work, which usually include brief presentations or deliveries by the students. Teamwork is common but individual submissions may also be considered.

- Field visits to the project site or some other interesting place for the project.

The course is structured in different phases, usually divided into tasks related to the project. That is, it facilitates the resolution of a complex problem (project) by breaking it down into simpler problems (tasks), which in many cases may coincide with the phases of the project mentioned above (analysis, proposal, development). For each of the tasks, the theoretical content that the students will need is analyzed. This knowledge can be explained by the AT or CT or acquired through complementary tasks (for example, bibliographic consultations or Internet searches). Finally, the AT has to clearly identify in which part or task of the project each of the learning outcomes of the subject is worked on.

The CT can help to engage student interest and set the stage for a project from the very beginning. A visit to the Faculty or a field trip to the company location will pose the project challenge, kick off student inquiry, and provide an authentic “real-world” context for the project work that will follow. The role of the company in the initial phase of the presentation of the project to the students is crucial, since it gives veracity to the project, connects it with the professional reality of the students, and motivates and justifies the need to acquire the knowledge related to the subject.

Throughout the project, it will be necessary to establish at least one revision session of the students' work with the company tutor. Not only will partners be able to provide valuable feedback to students that is grounded in deep expertise, they may even be willing to share the critique and revision processes that they use in their own professional contexts. This revision is fundamental for the definition of the students' proposal and its adaptation to the reality of the project.

Finally, it is convenient that the students present a final synthesis of the project, especially if the course is organized around it. This final presentation summarizes the phases followed and includes the criteria used in the definition of the solution and the justification of the proposal and its final design. This is the most appropriate moment for the company tutor to make his last visit and collaborate in the evaluation of the projects. Knowing that they will be sharing their work with an audience of experts motivates students to create high quality work and validates the hard work that students put into their project development.

During this collaboration with the company, it is important to find a balance between the availability and level of involvement of the company tutor and the needs of the project. The timely but continued presence of the company tutor is essential to give the project a sense of reality and professional work and engage students. Moreover, the discussions with the company tutor during the workshops, as well as his comments during the students' presentations, enrich the learning of the students who receive feedback from someone other than their teacher, who has a less academic and more professional profile, usually more connected to the professional reality of the moment.

2.2 Implementing PCCs in the Civil Engineeringcurricula

The idea of introducing dual training or collaboration with the company in the curriculum of some of the degrees of the Faculty of Engineering of Gipuzkoa arose in the 2017/18 academic year. In this academic year, some experts in the field were invited and the teachers of the Faculty and the departments involved where invited to study the possibility of implementing this model in their subjects.

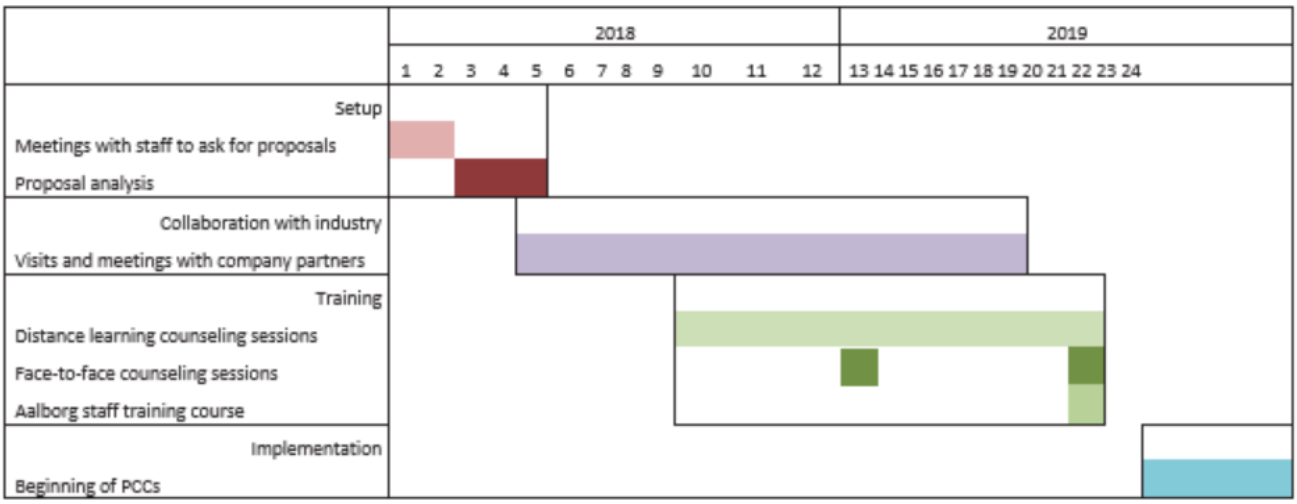
In the 2018/19 academic year, the Civil Engineering degree had a sufficient number of expressions of interest to start the process. During this academic year, three training and reflection sessions were held with a reference person in this field. The aim of the first three sessions was to tutor and help each teaching team on the best way to adapt their subject to the methodology of the PCC. Thus, these three sessions were distributed throughout the course (November, January and May) since at the end of May the EHU requires the departments to publish the teaching guides of the subjects, which must detail the teaching methodology to follow as well as the evaluation of the subject.

Besides, an agreement was established between the Aalborg UNESCO Centre for PBL in Engineering Science and Sustainability (Aalborg University, Denmark) and the Faculty of Engineering of Gipuzkoa. The overall goal was to inquiry the academic staff needs and expectations for pedagogical training and development in engineering education. Specifically, the aim was to plan, run, monitor and research a pedagogical intervention in shape of a crash course for academic staff at the Faculty of Engineering of Gipuzkoa. The staff-training course on "*PBL and integration of industry projects in curriculum*" was problem-oriented, exemplary and experiential, where participants developed basic understanding on PBL, PBL curriculum and course design, and integration of industry projects. It was held in July 2019.

With regard to the participation of companies, each department/teaching team identified the company or companies that could be most suitable to collaborate with the PCC. One of the criteria when selecting the company/entity was the existence of some previous contact with it. In some cases, where there was no previous contact, the principal of the Faculty established the first contact. Accordingly, throughout 2018/19, visits were made to the companies to agree or discuss the type of project in which they would work as well as the conditions of participation of the company tutor.

Finally in 2019/20 most of the courses started with the PCC methodology. In table 1 the timeline of the implementation process is shown.

Table 2: Timeline of PCCs implementation



2.3 Evaluating PCCs in Civil Engineering curricula

The evaluation of PCCs model focus in: (i) students' self-perception about their learning and degree, and (ii) course standard evaluation carried out to all courses carried out in a given semester.

Regarding students' self-perception about their learning and degree, two questionnaires were distributed: one before (pre-test questionnaire) and one after (post-test questionnaire) the winter semester of 2019/20. Questionnaires were distributed in class, so the number of responses is equal to the number of questionnaires distributed. At the beginning of the course 19 questionnaires were distributed and 12 at the end of the course. The difference of responses before and after the course is due to students who drop out the course. The scale used was in a 5-point scale. The aim of these questionnaires is to approach the student's view of the degree and to check whether this new teaching method significantly improves the student's perception of the degree. Figure 2 shows the results. In overall, results show that student's satisfaction with his or her training improves significantly. Students give a more positive evaluation of the complementary activities carried out, the acquisition of transversal skills, the applicability of what was studied as well as the contact with the professional world (Figure 2). In conclusion, the PCC model address two of highlighted priorities above, which are strengthening the university-business relationship, and promote the role civil engineering has in addressing social and professional challenges.

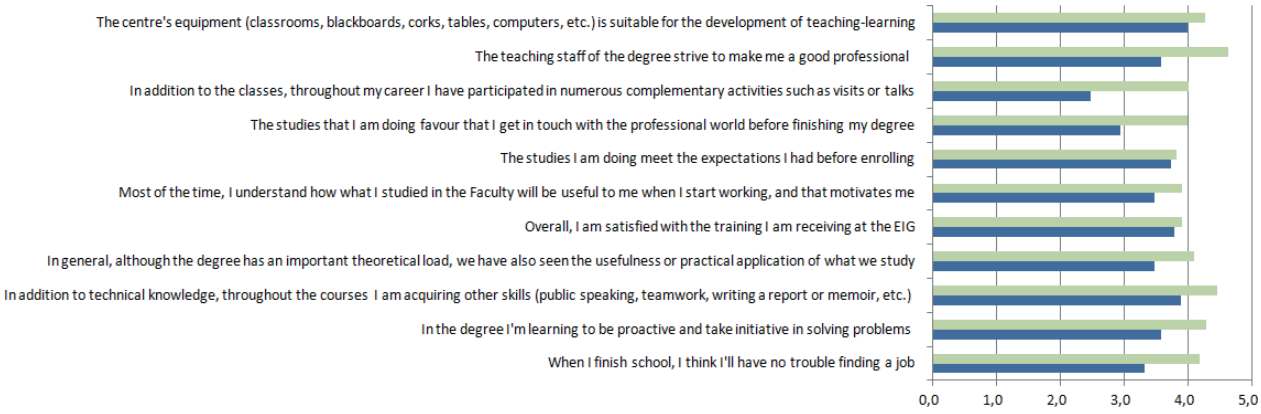


Figure 2: Students' self-perception about their learning and degree before (pre-test questionnaire in blue) (n=19) and after (post-test questionnaire in green) (n=12) the PCCs course.

Every semester students must answer a teacher's survey, which inquiry about their learning experiences by evaluating each one of the subjects they have studied. Figure 3 shows the comparison of the evaluation results of one of the subjects which has been adapted to PCC: the 2019/20 (PCC) and 2018/19 (non PCC). In 2018/19, there were 25 students enrolled in the course and 15 answered the survey, whilst in 2019/20, 19 students were enrolled and only 10 answered the survey. In this case, the results on the teaching given also improve significantly. All items improve except two (one is maintained, the other drops 0.1 points). The improvement is particularly noticeable in the questions related to student self-assessment (i.e. that students evaluate themselves better, in terms of the work done) and learning assessment, where it goes from an average of 2.8 to 3.5 out of 5 (Figure 3). In conclusion, students' have a better learning experience when in a course using PCC model. Furthermore, the results are also aligned with students' self-perception of degree and their development.

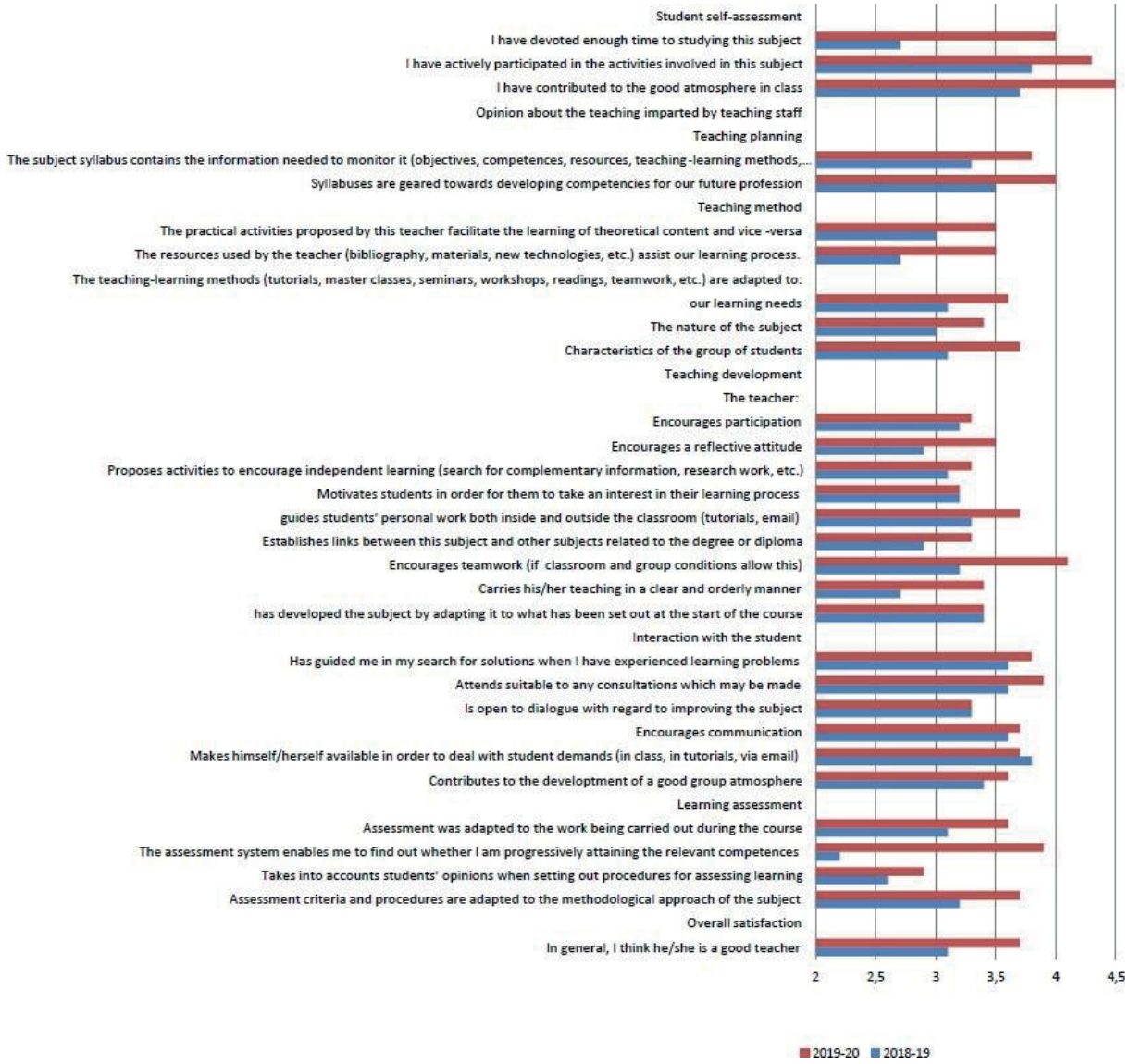


Figure 3: Course evaluation: comparison between non-PCC course (in blue), semester 2019/ 2020 (n=10), and PCC course (in red), semester 2019/20 (n=15).

3 Final reflections

This paper describes the strategy of the Faculty of Engineering, Gipuzkoa (University of the Basque Country UPV/EHU, Spain) implemented with aim of developing a more innovative engineering education by re-organising their courses around projects and in collaboration with companies. Furthermore, the Faculty's strategy is compressive, meaning that includes different strategies giving the students different learning experiences in contacting with work place and employers in different moments of their education. The PCC course model was evaluated using two questionnaires: one inquiring about students' self-perception of their learning and degree, and the standard course evaluation carried in all courses of the Faculty. In overall, students provide a positive evaluation of the course and the complementary activities that are integrated into and form part of the PCC model. They also are very satisfied with the development of their transversal skills and early contact with companies. Regarding the standard evaluation, when comparing with non-PCC courses (i.e. courses that do not follow the PCC model); students also provide a positive

feedback. The results here presented are part of the piloting of PCC model in civil engineering curriculum; however, the results and experiences gathered enable to formulate some reflections to consider in the future development of the pedagogical model.

From a staff development perspective, it is needed more and focused pedagogical training to develop further their pedagogical skills and competences. The primary area of expertise of engineering educators is in engineering and therefore, we cannot expect that they have the suitable pedagogical knowledge and competences to start innovating and change their courses and practice towards more student-centred learning. The faculty has collaborate with Aalborg UNESCO Centre to provide earlier training on PBL, curriculum/ course design and collaboration with industry. However, the development needs to continue internally, not only to engage more academic staff towards a more systemic integration of PCC model, but to also develop community of practices for mutual support and learning.

From a learning perspective, the students' evaluation indicates we are moving the right direction in improving their learning experiences and create meaning to their development, namely development of transversal skills. The results also raise aspects to consider to move forward and take more research-based approach to change process, namely in which ways the PCC model increases students' motivation, or what are the implications in the attraction and retention of students in the engineering programmes following PCC model. No survey or questionnaire regarding the role of the company tutor on strengthening students' competence development was conducted, but definitively this will be taken it into account as future line of work.

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