A CASE STUDY OF A PROJECT BASED LEARNING ACTIVITY IMPLEMENTED IN A GEOTECHNICAL ENGINEERING COURSE

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Abstract

Today’s industry employers are looking for graduate civil engineers that not only have acquired strong and sound technical and scientific knowledge but also should they have good problem-solving, teamwork, writing and communication skills among others. At present, civil engineering programs and courses are mainly delivered using traditional teaching methods that have been proved to provide a good technical, scientific and engineering knowledge among their graduates. However, in most cases, there is a lack of practical and design experience as well as a low development of the previously mentioned personal abilities in their graduates. Project based learning (PBL) strategy has been proved to be effective addressing most of the shortcomings presented before in engineering courses. Thus, in this context, one PBL activity has been introduced as part of a geotechnical engineering course within a civil engineering degree. A mixed strategy of traditional teaching and PBL has been chosen not to sacrifice the scientific, technical and engineering fundamentals knowledge. The implemented PBL activity involves the design of a small-scale deep foundation prototype, that will be printed in 3D and subsequently, it will be tested in the laboratory. This paper describes the PBL activity, together with the perception of the experience from the point of view of the students involved.

Keywords: project based learning, teamwork, problem-solving skills, engineering education.

1 INTRODUCTION

Nowadays to be a successful civil engineer it is not enough with having a strong technical and scientific knowledge as industry stakeholders require graduates to have all this knowledge together with social skills and good problem-solving abilities [1]. Among this abilities teamwork, good communication skills, managerial skills in combination with practical experience, are the ones more demanded and less developed in the current civil engineers graduates [2]. Traditional teaching methods are still dominating engineering teaching practice, being lecture-based the main delivery mode. This methodology has been used since 1950 and it has been proved to be effective for acquiring strong and sound technical and scientific knowledge, but less efficient for acquiring practical experience, social skills and the abilities presented before [2]. Thus, changes should be implemented in the current engineering curriculum design and teaching practice to address the lack of development of these required skills, and increase students’ motivation.

Several approaches have been proposed to overcome previously presented shortcomings and to follow Bologna declaration principles by developing students’ competences [3]. Most procedures require sifting to students-centred teaching strategies and active learning environments, leaving behind the teacher-centred approach associated with traditional teaching practices “chalk and talk”. It is worth nothing that most of the tasks in engineering professional practice are in relation to projects. Their time, scale and their complexity are variable and can involve just one or more areas of specialization. Thus, considering all the above and constructivism as a theory frame, one suitable approach to enhance engineering courses is to introduce Project Based Learning (PBL) strategies.

A simple definition of PBL is the one given by [4] “it is a model that organizes learning around projects”. Ribeiro [5] nuanced the definition by saying that the projects are representative of real-life situations. Du et al. [6] defines PBL as a new learning philosophy where active learning is the centre. Therefore, the students are active in the process of turning information into knowledge [2] [7]. Sometimes project base learning and problem based learning are interchanged. Both learning strategies are similar as they are based in collaboration and self-direction, but the first one is more directed to the application of knowledge and the latest is more dedicated towards knowledge acquisition [8]. In addition, PBL tasks are closer to real professional activities, they are more centre in applying knowledge and usually, time management is an important factor. Furthermore, PBL is commonly complemented with subject courses, what is important for acquiring engineering knowledge as its nature is sequential and have core areas [2].
PBL has been applied to engineering teaching practice since the 70s, but it has just been recently when it has brought the attention to the international engineering education community [6]. This might be due to the difficulty of assessing PBL implementation success when comparing it to traditional teaching methods [9]. Nowadays PBL has been proved effective in developing the expected engineering graduates’ skills [9]. Aalborg University of Denmark project-based engineering program is the most well known example of PBL curriculum [10] and it is one evidence of this strategy effectiveness. Other successful experiences of PBL have been implemented in Central Queensland University in Australia [11] for the first year courses of civil engineering, and in individual courses in different engineering degrees in the UK [12]. These examples show the positive methodology performance and underline the current popularity of PBL strategy in engineering education, as it is becoming one important feature. Nevertheless, PBL application experiences in engineering courses in Spain are limited [13]. There are just few examples [8] [14] [15] and most of them are just performed within an individual course and not for the whole degree curriculum. This might be due to the limitations of faculty time, faculty experience, resources, learning spaces and accreditation concerns, which are some of the barriers to PBL implementation [12].

Considering current PBL strategy popularity and the lack of examples in engineering courses and curriculums in Spain, this paper describes one example of a PBL activity implementation in a last year module of a civil engineering degree in Spain. It also analyses its impact on the overall student learning experiences.

2 ACTIVITY DESCRIPTION AND CONTEXT

The PBL activity was implemented in the civil engineering undergraduate program of the University of Cantabria. The module where the Project based learning activity was first put in action is taught in the first trimester of fourth year (last year) of the Civil engineering Degree. It is a compulsory course for the students undertaking the specialty of Civil Constructions and it is taught in English. It is the second course related with geotechnical engineering, and its name is Geotechnical Works. In this case study, the PBL was implemented as part of the teaching-learning strategy and it was complemented with traditional lectures and tutorials not to compromise the scientific, technical and engineering fundamentals knowledge [2]. It was introduced for the first time in September 2018 as an optional activity. A total of 30 students were involved in the activity. They were around the 75% of the whole cohort of students. The other 25% were the ones that are part-time students or have time restrictions.

The PBL activity objective is for each group to design a small-scale deep foundation, which is built by means of a 3D printer. Once the prototype is built, it is tested in the laboratory to see its behaviour and the effectiveness of the designs. Finally, a discussion session is made to present all the designs and to comment about the different factors influencing the behaviour and effectiveness of the models developed.

Students worked in small groups of 4 or 5 people (7 groups), to solve this open-ended problem. The whole PBL activity was developed during 8 weeks around 50% of the duration of the module. Initially, each group was given a brief where the activity and all the process was explained together with the data needed to develop their design for the clients (academic staff). They were given the soil conditions, the printer capabilities, material characteristics, and the design load the foundation should withstand. During the project development, there were 5 points of delivery which correspond to the different project stages. Only the last two deliveries were part of the summative assessment. The first three were just part of the design process and similar to the different stages in a real project.

1st delivery. (Initial design) Each group needed to present and explain to the clients (academic staff) their first design prototype. During this presentation, the clients could ask for explanations about the design process or could suggest some changes to the design.

2nd delivery. (Final design) One week after the first delivery, each group presented their final design of their prototype. The client printed the final designs handed.

3rd delivery. (Testing session) Two weeks later, the prototypes were printed and ready for their testing, as presented in Figure 1a. A load-displacement test for each prototype was performed individually for each group. The members of the group prepared the soil layer in the way their considered optimal to achieve the properties given in the design brief. The soil employed was sand and it was placed in a cubic Perspex box up to a height of 22 cm. Before the installation of the prototype started, the density of the sand was checked to be sure that the conditions given were achieved. The prototype was then installed in the centre of the box and then, the load-displacement test was performed. The setup is
shown in Figure 1b. One centimetre was left between the top of the soil layer and the bottom of the pile cap not to have the influence of the pile cap in the small-scale test. This is because the influence of the pile cap is higher in small-scale tests than in real life, in situ. The load was applied following a rate of 1 mm/min. Results were monitored live allowing the students to see the behaviour of the prototype during the test. Once the test was finished, the load displacement curve was given to the students so they could see the differences between the design and achieved load. A brief discussion was generated after the testing.

![Figure 1. a) Groups prototypes b) Set up of one prototype load-displacement testing](image)

4th delivery. (Oral presentation) One week after the tests, a discussion session with all the students took place. Each group gave a 10 minutes oral presentation followed by 5 minutes of questions made by the clients (panel of academic staff). Each group presented their design process, their experimental tests results, a comparison with the expected results and the potential causes of the discrepancy between the achieved and expected values. Once all the groups had presented, to close the discussion session, the academic staff made a summary of the causes influencing the behaviour of the prototypes.

5th delivery. (Portfolio) One week after the oral presentations, the portfolio was handed. This portfolio is a document that summarizes all the deliveries plus a final section where the potential causes influencing the behaviour of the prototypes were described.

These were all the stages and deliverables of the PBL activity. All the deliveries were handed on Moodle except the oral presentation and the laboratory testing of the prototype that were made live. The summative assessment took into account just the last two deliveries as presented before.

3 METHODOLOGY

A Questionnaire related with the PBL activity implemented was developed to be able to obtain the students’ perception of the activity. The questionnaire is similar to the one employed by [8] when evaluating the impact of their implemented activity from the students’ perception point of view. It has 11 questions, 9 of which should be answered just selecting one option of the scale given and two of them were open questions. The final questionnaire was completed by 45% of the students involved in the PBL activity. Although this rate of participation is not as high as expected, it allows to make a preliminary analysis of the students satisfaction, as it will be complemented with comments given to academic staff during the face-to-face sessions. Nevertheless, for the future, attempts to enhance students’ participation will be implemented. This can be done by promoting incentives or delivering the questionnaire in paper and giving time to complete it during the last session. The complete questionnaire is presented below.
Please answer the following questions based on the scale:

<table>
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<th>Very important</th>
<th>Completely agree</th>
<th>Important</th>
<th>Neutral</th>
<th>Unimportant</th>
<th>Non important at all</th>
<th>Not Applicable</th>
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<tbody>
<tr>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>X</td>
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1. Was the aim of the project clear?
2. Was the aim of the project accomplished?
3. Are you convinced that the knowledge acquired is useful?
4. Did this project development contribute to your learning?
5. Was previous knowledge sufficient for the project development?
6. Was class development compatible with project development?
7. Was attendance to consultation important for project development?
8. Did your group work together and integrated?
9. How do you rate the overall project development?
10. Would you change anything of this project? What changes would you introduce?
11. Any other comments related with the project.

The aim of the questionnaire is getting to know the perception of the students about this new implemented PBL activity. In addition, their attitude and their involvement during the development of the PBL activity is going to be analyzed based on the perception of the academic staff.

4 RESULTS

The questionnaire was available to all students that took part in the project once it was finalized via Moodle. From their answers the results derived in terms of questions average, mode and deviation values are presented in Table 1. The answers scale goes from 5 (very important/completely agree), unit 1 (non important at all /completely disagree), as presented before.

<table>
<thead>
<tr>
<th>Table 1. Student’s perception results</th>
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<td>mode</td>
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<tr>
<td>Was the aim of the project clear?</td>
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All the points addressed with the questions received a good rating form the students resulting in values above 3.8 out of 5. The strongest points were that students found the aim of the project clear and that they perceived the knowledge their acquired with the project development as useful for them. This was strengthen by some contributions found in the additional comment section of the questionnaire where several students wrote positive comments related with the activity. Some of them are: “we were able to take decisions and choose, what helped us understanding the procedure”, “it is a different way to learn, not just doing exercises”, “it is a new way of acquiring knowledge”, “it is a way of applying the theory we
have studied in a practical way”. In addition, talking with the students, they had in general a positive perception of the activity and they think it has helped them in their learning process. The answers given did not say why they thought the PBL activity was helpful in their learning process, so it should be specifically asked in the future to find it out.

The weakest points were the compatibility with class development and the overall project development. In relation with the compatibility, some students complaint about the amount of work they needed to develop the project while they were having classes. Comments in the same line of thinking were the ones that gave the low rating to the overall project development. Several students wrote on the additional comments that they have spent more time solving the project than they initially thought and they thought more time should be given to do it.

Students gave more information while developing the project to the academic staff during face-to-face sessions: laboratory testing and oral presentations. Most of the comments were related to the oral presentation and some with group work. Most of the students did not want to present their work in front of the class. This might be because they are not used to present their work in front of others and in this case, there was and additional problem, the language. It is important to know that they were asked to do the presentation in English, as it is the language of the course. Finally, from other comments it was clear that some groups have problems working all members of the team together and some students worked more than others did.

These answers and comments provided by the students have arisen some points of the project that can be improved. These are related with the time scale, the management of the project at the same time as classes and working in groups. Actions have been proposed to improve these weak points and enhance the activity for future applications. The time to perform the project has been increased. In the future experience, two weeks are given to present the initial design and then three weeks to present the final design. This means an increment of at least one week for each of these deliveries. To solve the problem of working in groups, the use of online tools has been promoted. Each group has now a Wiki in the course Moodle page which they should update with their work about the project. This allows all members of the group to participate and collaborate easily in the activity. The information of all groups will be shared after each delivery with the rest of participants with the idea of generating more interaction between groups. This will also help to endorse the collaboratively learning atmosphere.

5 CONCLUSIONS

The purpose of this training proposal is to provide a framework for active learning sustained in real situations that connect with the type of knowledge and skills that are demanded by industry stakeholders for the professional life. The experience presented shows a positive first implementation of a PBL activity as part of a course in Civil Engineering. The analysis of the project developed by the students has demonstrated, in coherence with [2] and [5], that the PBL has contributed to strengthen the connections between theory and practice. In addition, it has helped to develop another conglomerate of skills (collaboration, communication, problem-solving, etc.) as well as technical knowledge. Likewise, the perceptions of the students regarding the PBL development are good. Most of them emphasized that it was a new way of working and learning and they liked it. However, this PBL implementation is a partial implementation in an isolated subject, and a first step towards a broader PBL strategy implementation. In this line, students’ responses have also helped to discover the weak points of the project. To enhance them, changes for future implementations have been proposed. Changes in the time scale of the project and promoting the use of online tools to improve the collaborative learning have been performed. These new improvements will hopefully improve students experience and enhance the PBL activity. They are already being implemented in the current application to another similar course.

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REFERENCES


