SUCCESSFUL CASES AND LEARNED LESSON AFTER TWO COURSES USING PBL+ FOR PRACTICAL TRAINING OF ENGINEERING STUDENTS

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Abstract

PBL+ is the acronym of Problem Based Learning Plus, which is a teaching-learning technique developed by the Teaching Innovation Group INGENIAQ from the University of León (Spain). PBL+ gathers different teaching-learning techniques including the PBL classical methodology, flipped classroom, evaluation through the use of rubrics and service-learning. PBL+ has been specifically developed for engineering courses, in order to achieve the competences related to the immersion of students into the business world. PBL+ was designed to be specifically applied in the practical activities associated with engineer lectures, i.e. it was not designed for the curricular or extra-curricular practices. With this methodology, the students get into direct contact with companies, facing a real problem. The collaboration of a commissioned person from the company is a key point to achieve the expected competences completely. Currently, PBL+ has been applied in two complete academic courses and tested 25 times involving more than 350 students from 10 different engineering degrees or masters. Therefore, the teaching group has gathered enough experience and data regarding the use of the PBL+ methodology, being possible at this moment to perform an assessment of results. This work describes a SWOT (strengths, weaknesses, opportunities, and threats) analysis, explaining successful cases and learned lessons. COVID19 pandemic burst into the Universities and involved the adoption of solutions to shift from a face-to-face teaching-learning system to a blended system, and this also affected the application of PBL+. Because of this contingency, the PBL+ system was applied in partial virtual teaching-learning system. As a consequence, the performance of the methodology indicated that engineering studies do not adapt well to distance learning.

Keywords: PBL+, Problem Based Learning, rubrics, service-learning, flipped classroom.

1 INTRODUCTION

The Problem Based Learning Plus (PBL+) [1] is an improvement of the classical Problem Based Learning methodology that was developed in the mid 80's of XXth century [2] [3]. PBL+ has been developed at the University of León (Spain), by the Teaching Innovation Group in Agro-environmental and Chemical Engineering to serve as a teaching methodology for practical classes in Engineering, although it can be replicated in all the STEM (Science, Technology, Engineering and Mathematics) subjects [1]. In the PBL+ methodology, a real problem from a real company must be solved by the students, ideally with a direct contact between the student and a commissioned person from the company [4]. PBL+ combines different learning-teaching techniques, in such a way that their components are the following: i) the original problem-based learning [2, 3]; ii) the flipped classroom [5, 6 and 7]; iii) service learning [8]; iv) the use of rubrics for evaluation [9,10, 11 and 12].

The COVID19 pandemic bust into the Universities forcing to adopt dramatic changes in the very short term, in the learning-teaching process [13, 14]. PBL+ was designed for the world existing before march 2020, and thus it needed adaptation. Urbano et al. [4]. According to the mentioned work, the visio conferences cannot replace the in-person exploration of the processes in which the problems to be solved are born. Out of the four components of the PBL+, the service learning was the worst adapted to mixed or entirely online systems, whereas the flipped classroom showed the better adaptation. Moreover, the mixed and online systems fail to achieve the competences related to the oral communication skill, critical thinking and neither the technical knowledge and skills.

This work analyses the application of the PBL+ during 2 academic courses. For the analysis, we have selected three different subjects, which represent the different knowledge areas included in the curricula of an Engineer. The Engineers must be skilled in production, and also in the socio-economical aspects

related with their professional activity. In consequence, from the 11 subjects in which PBL+ has been applied, we have selected one related with processes engineering in agro-environmental studies, another one is related with production engineering in bioprocesses, and the third one is about socioeconomical aspects of engineering. For the analysis it has been considered internal and external conditioning factors, such as the business sector, e.g. agricultural or industrial sector, and the external conditions as for example the changes that the pandemic COVID-19 has imposed in the labour world.

2 METHODOLOGY

The subjects selected for the present appraisal were the following:

- Processes engineering in the agro-environmental studies: “Cropping systems”.
- Socio-economical aspects in engineering: “Business administration and agri-food marketing”.
- Processes engineering in the bio-processes: “Biotechnological processes”.

The positive aspects and learned lessons after two academic years of application of the methodology in each subject were gathered by the responsible teacher and briefed in this work. The tools used by the professor in charge of the activity to collect the information were the following: i) survey to the teachers participating in the subject; ii) survey to the students to know their opinion about the activity; iii) survey to the company representative about the activity; iii) comparison between the auto-evaluation of the students and the teachers’ evaluation using the specific rubric developed for this activity. This is an objective indicator about the performance of the methodology.

With all the information, a SWOT (strengths, weaknesses, opportunities and threats) table was developed to evaluate the PBL+.

3 RESULTS

3.1 Cropping systems

3.1.1 Description of the activity

Cropping systems is a subject from the Master in Agricultural Engineering. The general, basic and transversal competences are those typical of a Master degree: i) technical knowledge and skills; ii) synthesis capability; iii) critical thinking; iv) written communication skills; v) oral communication skills. The specific competences are related with the control and design of processes of crops production, including all the aspects related with it as for example the structures for controlling climatic and soil conditions, plant protection systems, soil fertility control, etc. The agri-food industries and husbandry are excluded.

In the PBL+ activity, the students select a company by themselves based on their own preferences. In such a way, the students are well motivated to make the activity. They are proposed to select a company whose field of activity is related with the topics of the subject, and to get in touch with the chief executive office (CEO) in a face-to-face meeting. The purpose of such meeting is that the student receives direct information about a real problem of the company that needs a solution. In order to apply the PBL+ methodology, the CEO must be in a position of sharing the problem with the students, and to accept to give the necessary information to the students, to make their work. The students introduce themselves as Engineers who are currently taking a Master’s degree, and thus they must convince the CEO about their capability to solve a problem and their professionalism to keep the confidentiality conditions imposed by the company. The CEO in turns receives a free consultancy an also the support of the University professors and the access to scientific and technical databases.

During two years, the most popular collaborating companies were cooperatives, and agricultural supply companies. Besides, one agro-industrial company collaborated with his agronomic department. It offered a problem related with the agronomic management of the crop that caused further problems with a part of the industrial process, and the student worked on the agronomic problem.

The activity was tackled at the beginning of the course, using the flipped learning methodology. The progress of the work was discussed between the student and the representative from the company face-to-face or by telematic means. Concurrently the progress is presented to the teacher and the rest of the students. At the end of the activity, the final conclusions are presented to the teacher, the rest of the students and the representative from the company,

3.1.2 Positive aspects encountered

Intriguingly, the agricultural sector was very collaborative with this activity, and they accept to participate. In this sector there was no reluctancy about confidentiality issues.

The reaction of the students has been very positive, as they feel that the activity brings the students closer to the professional world. However the marks can be considered low at the beginning and they did not improve until we stablished a clear evaluation criteria using rubrics (see section 3.1.3).

3.1.3 Learned lessons

Such an atypical activity needs to be well explained to the students, so that they are able to understand what it is expected from them. In consequence, the first design for the PBL+ activity that did not include the rubrics, produced low marks due to the lack of understanding by the students about the activity. To solve this problem, the last version of PBL+ included a rubric for evaluation [11, 12, 15]. The rubric was provided to the students at the very beginning, so that, knowing the indicators to be evaluated, the students were aware about the competences they need to acquire.

Table 1. SWOT for the application of PBL+ in the subject "Cropping systems" from the Master in Agricultural Engineer.

Strengths	***Weaknesses***	***Opportunities***	***Threats***
The involvement of a company in the learning-teaching process	PBL + is not well adapted to online distance learning	The possibility of improving the subjects' programming with the information obtained from the company	The limited number of local companies could deplete the available topics
The students feel positive to get in touch with the professional activity	Each student become an expert in the cropping system analysed but has very reduced contact with the rest of the cropping systems	It may improve the employability as some students can be contracted by the company where they performed the activity	the companies can get wearied from the repetition of the activity year after year and they can decline collaboration
The PBL+ activity is an effective simulation of what is "real professional life"	The activity has partially failed in achieving the "critical thinking" competence	This activity can improve the collaboration univerisy-companies	The differences in the difficulty of the different problems can affect to the equality of opportunities

3.2 Business administration and agri-food marketing

3.2.1 Description of the activity

An activity in four steps was developed. In the first step, the teachers collected criteria and indicators for the assessment of competences in Higher Education, in our case for the subject of Business administration and agri-food marketing at the Master of Agricultural Engineering. The competences were collected from the study programmes endorsed by the Education National Ministry. Three following competences were tackled with the activity: i) Capacity to analyse and summarise (C1); ii) Ability to communicate both in technical and non-expert forums (C2); and iii) Critical thinking (C3) according to the study programme.

In the second step, the students scored the criteria at the beginning of the semester in order to consider the rubric from the first moment of the teaching process. In the third step, the teachers discussed the indicators and criteria and created the rubric. In the fourth step, the rubrics were completed during the evaluation process and the students scored their level of acquisition of competences. Finally, the teachers discussed and compared data giving feedback to the rubrics for the assessment of competences

3.2.2 Positive aspects encountered

The teachers expressed that rubric is capable to measure the progress, evolution and acquisition of competences by the students according to the European Higher Education Area (EHEA) learning process.

The students granted more to the practical solutions needed to solve the market problems than to the formal aspects.

3.2.3 Learned lessons

The students give less importance to provide their own recommendations and future line of action than to analyse the problem. As a consequence, the competence less achieved was students´ critical thinking, whilst the competence most achieved was the capacity to analyse and summarise. The observed lack of critical thinking in the projects indicates that efforts must be done by students and teachers to improve this competence.

The teachers noticed that the students lacked of self-evaluation ability, being unable to evaluate the quality of their work quality and the possible improvement.

Table 2. SWOT for the application of PBL+ in the subject "Business administration and agri-food marketing" from the Master in Agricultural Engineer.

Strengths	***Weaknesses***	***Opportunities***	***Threats***
The rubrics allows the teacher evaluation within the students' self-evaluation and co-evaluation.	The competence less achieved both students and teachers was students´ critical thinking.	The students declared that they enjoyed interacting with companies communicating with them, reading comments about the company and obtaining their own conclusions.	It was found a significant difference in the assessment, males gave significant higher marks than females. This result could be explained due to the gender bias in technological contexts proved by [16], where females were presented with less technology skills than males.
The teachers expressed that rubric is capable to measure the progress, evolution and acquisition of competences by the students according to the European Higher Education Area (EHEA) learning process	The students presented higher importance in practical solutions to agricultural engineering market problems than formal aspects	The students eulogise their colleagues' work, which help them to learn and progress while seeing the ways to improve their own work	The teachers noticed the students´ lack of self-evaluation ability.
This project contributed to the alignment of the evaluation with the competences, the student's follow up of his own activity.		This project favours their responsibility of the learning and the self-evaluation of the quality of their work and the ways in which it could be improved	The assumption of students' responsibilities in the teaching-learning process using rubrics is a challenge for them

3.3 Biotechnological processes

3.3.1 Description of the activity

This subject is included in the program of the Degree of Biotechnology. The subject deals with the evaluation of performance of biological systems considering technical aspects and also including technical criteria for the design of biotechnological process and analysis of their economic feasibility. The course belongs to the fourth year of studies, therefore students taking this subject have a high degree of responsibility and maturity.

The main objectives of the course are dedicated to estimate main factors affecting production of biotechnological products and ways of improvement. There is a wide variety of factors that make impossible the direct relationship of students with the industrial biotechnological sector, as it is, the compliance of security standards, sanitary regulations and professional know-how risks. Therefore, the methodology was adapted in a way that allowed for students learn on their own basic theoretical concepts that are applied at an industrial level.

The application of the PBL+ methodology then consisted in selecting a waste treatment technology which is dedicated to valorising organic wastes. In this case, anaerobic digestion was the subject selected. Students were asked to search methodological parameters based on previous knowledge acquired and skills that need to be developed to solve the problematic of waste treatment. The problem

resolution cover aspects regarding the measurement of methane potentials and the extrapolation of this concept to a plant design, finalizing with the search of commercial companies dedicated to the design of this type of plants, considering their location and contact information.

3.3.2 Positive aspects encountered

Most of the information obtained by the students was based on scientific data bases and webpages, most of them in English language. The majority of students were capable of understanding the information reported in these data bases. The use of rubrics to evaluate this particular exercise allows students to focus on specific evaluating parameters, having this way a useful guide with the relevant aspects that have a major incidence in the final grade. This way, they can focus on the main task and work by keeping an alignment with the objectives linked to the assignment.

3.3.3 Learned lessons

The specific parameters associated with the physical way of performing the tests described in the scientific literature were not clear for most of the students until teaching explanations were given. In addition, it was observed a high degree of insecurity about the information they were assimilating given the intrinsic variations found when performing these laboratory assays. In spite of this, we consider that we must keep the flipped lesson strategy, because it is the best way to show up the key aspects that need more attention during the teaching explanations.

Regarding the evolution of gaseous products, just one student applied concepts previously studied in their Science studies. It was observed that students recall knowledge studied in previous years but their concepts were not so clear to allow the direct application of these resources to solve a specific problem with immediacy. For this reason, the PBL+ can help the students to apply their previous knowledge to the solve practical problems.

The aspects dealing with the design of the installation and searching for the company contact information was particularly new for them. This is because the study material is usually full of theoretical concepts that in many cases are hard to connect with commercial activities.

Table 3 shows the SWOT obtained from the PBL+ practical experience applied in the Degree in Biotechnology

Table 3. SWOT for the application of PBL+ in the subject "Biotechnological processes" in the Science Degree in Biotechnology.

Strengths	***Weaknesses***	***Opportunities***	***Threats***
The rubrics allows students to perform self-evaluation and discern the main aspects having impact on the final grade.	The competence less achieved both students and teachers was students´ critical thinking.	The students were more enthusiastic regarding the search of information with an applied focus.	The general application of this practice to the whole course is not feasible.
The teachers expressed that rubrics are a useful methodology for achieving the learning objectives of the subjects	Students showed difficulties in assimilating new concepts that were not previously explained by the teacher due to the tendency of the learning system to wait for approval.	Searching for information allowed contact with their partners and colleagues. Communication and cooperative work was fruitful	Self-evaluation and the excessive use of rubrics may become tiresome if extensively applied to all learning tasks
The application of this experimental exercise helps in closing the gap between theoretical knowledge and practical information.	There are still great difficulties in language skills. Scientific information and technical knowledge is mainly published in this language, thus understanding some concepts is more difficult for students with low English level	This project sets a great expectation of applicability and opens the door to changes in the way theoretical concepts are introduced	Implementing this methodology during COVID-19 pandemic has a high risks of for students not performing all tasks and low capacity of detecting these cases.

4 CONCLUSIONS

The PBL+ has proven to be a useful methodology for Engineering studies because it helps the students to connect the theoretical knowledge with business and entrepreneurial real situations. PBL+ may be considered a revolution in the way of introducing the theoretical concepts, and it makes more attractive the teaching-learning process. Interestingly it has been useful for the different knowledge areas that make up the training of an engineer, i.e. production engineering and economical aspects. However, the available public information accessible in scientific databases is overly theoretical, and it is difficult for the students to distinguish the information that is useful for the industry from the pure theoretical musings, and to select the useful information. Nonetheless this is a situation that will face the future generations of engineers, because the academic world spends huge amounts of resources in theoretical research with the only purpose of being published in academic journals, but in an important percentage, such a research will never be the base of fundamental knowledge necessary to improve or develop new industrial/agricultural/biotechnological processes.

PBL+ is an optimal activity to improve the competences related with critical thinking, but the activity has demonstrated that the students fail in this competence more than in the rest of them. The industrial/biotechnological sector is reluctant to share information with the students, unlike what happens in the agricultural sector; thus, the PBL+ in the industrial companies must be adapted, and the teacher needs to act as an intermediate between the company and the student, as it is not possible the direct contact company-student. The use of rubrics for evaluation is a key aspect for the success of the PBL+, but the abuse of rubrics may become tiresome. Finally, the distance learning was not adequate for the application of the PBL+ methodology in the subjects related with the processes engineering.

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