ADAPTATION OF THE PBL+ METHODOLOGY TO B-LEARNING AND ONLINE TEACHING

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Abstract

PBL+ (Problem Based Learning +) is a teaching methodology designed for graduate and master degrees in Engineering, which was developed by the teaching innovation group INGENIAQ at the University of Leon (Teaching Innovation Group in Agro-Environmental and Chemical Engineering) (https://ingeniaq.unileon.es/). PBL+ consists of a combination of teaching-learning innovations developed to provide engineering students with the competencies related to the practical activities included in the teaching guide of the corresponding subjects. In PBL+, the students face a real problem that is experienced by a real engineering company and having a close relationship with the subject being coursed. The teaching-learning methodologies gathered by PBL+ are the following: Problem Based Learning as the basic methodology, with the particularity that students must get in direct contact with a representative from the company whenever possible. The rest of the methodologies include flipped classroom, rubrics-based evaluation of the activity, and in some cases, service-learning. This methodology has proved very adequate for master's studies, in which the students' background and their academic maturity are adequate for implementing a flipped classroom where the problem to be solved is the starting line of the teaching-learning process. However, PBL+ has also been successfully used at the graduate level. For evaluating the activity, an adequate rubric has proved to be essential for students' correct understanding of what is expected from them. Due to the pandemic suffered by humankind during 2020 and 2021 by COVID-19, the teaching-learning process has suffered an unprecedented transformation, forcing to replace face-to-face activities with online activities. Even after the sanitary emergency subsides, and face-to-face classes return, the University will inevitably attend to an increase of what is called b-learning (blended learning), which is a mix of face-to-face and online classes. The objective of the present work was to analyse the effect produced by strict lockdown measurements during the first semester of 2020 in the application of PBL+. For such purpose, we analysed the emergency solutions adopted by teachers during the academic course 2019-2020, and changes in the teaching guide initially planned for the unforeseeable scenario for the course 2020-2021. Three scenarios with an unknown probability were considered as possible: face-to-face, online classes, and b-learning. As a consequence of the analysis carried out, we have established recommendations to adapt the PBL+ to online and b-learning. The adaptation encompasses changes in the relationship model with the company, changes in the group tutorship and the interaction between students, and changes in the evaluation rubric. Even if the PBL+ methodology can be adapted to online teaching, it fails on one of its main added values: direct contact between the company and the future professional. For b-learning, the PBL+ activity should, in most, be implemented in face-to-face classes.

Keywords: PBL+; problem based learning, blended learning, flipped classroom, online teaching.

1 INTRODUCTION

The PBL+ (Problem Based Learning +) methodology was developed to serve as a teaching methodology for practical classes in STEM (Science, Technology, Engineering and Mathematics) subjects [1]. It has been empirically demonstrated that PBL+ is a useful methodology to teach the competences related with practical activities in engineering degrees or masters, or engineering subjects in science degrees or masters [1]. In the PBL+ methodology, a real problem from a real company must be solved by the students. It is based on two main pillars: the first pillar is the combination of several pre-existing learning-teaching techniques, and the second pillar is the direct

contact between the student and a commissioned person from the company. Regarding the basic techniques that are used by PBL+, they are the following: i) the traditional problem-based learning [2, 3]; ii) the flipped classroom [4, 5 and 6]; iii) service learning [7]; iv) the use of rubrics for evaluation [8,9,10 and 11]. They are considered the four components of the PBL+ (Figure 1).
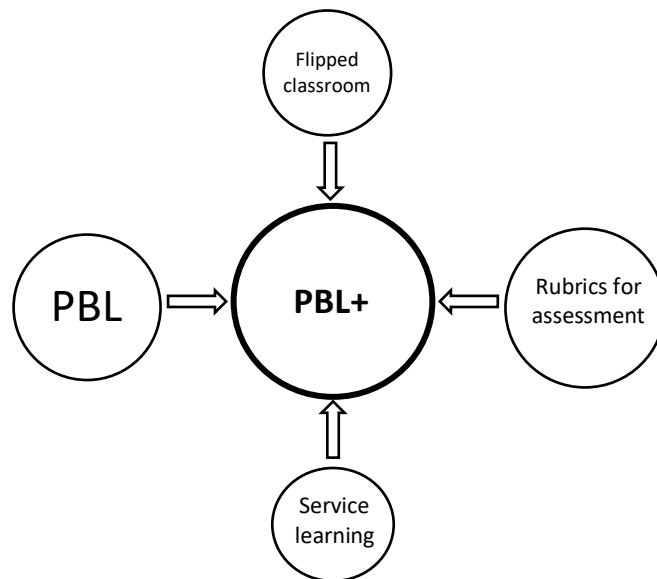

Figure 1. Components of the PBL+ learning-teaching methodology for practical subjects of STEM degrees and masters.

The COVID19 pandemic and the need for social distancing produced dramatic changes in the very short term, in the learning-teaching process and, as a consequence, digital resources burst on the University [12, 13]. This situation required a rapid adaptation to online teaching of systems that had been designed for face-to-face teaching. A general concern in the University community is if the system is prepared to face a similar situation in the future, and how to adapt the system to new scenarios in which the online teaching gains prominence.

In this situation a flexible learning-teaching system must be developed. Blended learning consists on a mix of different methods of delivery, styles of learning and teaching modes [14], and it can help to cope with changing scenarios as those produced by COVID19[15].

The purpose of this work was to assess the suitability of the learning-teaching system PBL+ to the new scenarios imposed by the pandemic. Such scenarios are characterized by a higher presence of blended learning (mixed learning face-to-face and online) and entirely online teaching in extreme situations.

2 METHODOLOGY

The methodology used is a semi-quantitative methodology based on a survey applied to the teachers pertaining to the Teaching Innovation Group from the University of León INGENIAQ. The surveyed teachers used the PBL+ system during the courses 2017-2018 and 2018-2019 (normal courses) and 2019-2020 and 2020-2021 (affected by the pandemic). The number of teachers involved was 7, and the number of subjects 11 (Table 1). In order to evaluate the affectation of the PBL+ methodology by the pandemic, the subjects involved in the survey were classified into three types (Table 1): i) process engineering; ii) management and economy; iii) environmental engineering.

The teachers were asked about two different aspects:

- The suitability of the different components of PBL+ to teaching in mixed systems (face-to-face and online simultaneously) in the one hand and entirely online in the other (Table 2).

- The degree of achievement of the different competences covered by the PBL+ in the same two cases indicated in the previous point (Table 3).

For both parameters (suitability and degree of achievement), the responses were structured in three categories related with the type of subject according to the classification presented in Table 1. The assessment was based in a Likert scale with five levels, being 1 the lowest suitability or the lowest degree of achievement, and 5 the highest one. In all the cases the comparison was made with the conventional system before the pandemic that is a entirely face-to-face system.

Table 1. List of subjects in which the adaptations of PBL+ methodology ot pandemic were assessed. Six of these subjects correspond to Master level and five of them to Degree level.

Subject	Degree/Master	Type of subject
Ornamental crops	Degree in Agrarian Engineer	Process engineering
Biotechnological processes	Degree in Biotechnology	Process engineering
Crops systems	Master in Agronomic Engineering	Process engineering
Innovation in the pharmaceutical industry	Master in Production in Pharmaceutical Industry	Management and economy
Business administration and agri-food marketing	Master in Agronomic Engineering – University of Valladolid	Management and economy
Agricultural and rural development	Master in International Cooperation for Development	Management and economy
Processes in carbochemical and petrochemical industry	Master in Mining and Energy Resources Engineering	Process engineering
Environmental technology	Degree in Electrical Engineering	Environmental engineering
Energetic resources management	Degree in Environmental Science	Environmental engineering
Aerospace sustainability	Degree in Aerospace Engineering	Management and economy
Chemical reactors and fermenters	Master in Production in Pharmaceutical Industry	Process engineering

3   RESULTS

3.1   Suitability of the different components of PBL+ to mixed systems (face-to-face and online simultaneously) and entirely online systems

Table 2 shows the average results obtained in the survey to the teachers involved in the use of PBL+, regarding the suitability of the different components of PBL+ to the mixed and entirely online systems respectively, designed to cope with the restrictions created by the pandemic COVID19. The average value serves as an indicator of the suitability of the full PBL+ methodology, considering the same weight for all its components.

A hurdle that needs clarification is what is understood by mixed system, because the percentage of face-to-face activities in a pandemic scenario are unforeseen. In principle, the face-to-face activity will be reserved for laboratory practices and also for the student's presentation of the PBL+ activity, but the interaction between the commissioned person from the company and the student usually suffers restriction because of limited access to companies' facilities. This inevitably affects to one of the most distinctive aspects of PBL+ which is the contact between the student and the company. Unfortunately, in the case of entirely online modality, in most of the cases, the teachers replaced the real problem by a hypothetical problem proposed by the teacher based on his own experience. This has an impact on the PBL component, that shows a suitability of 2.7 point out of five for the entirely online learning.

Table 2. Suitability of the different components of PBL+ to teaching in mixed systems (face-to-face and online simultaneously) and entirely online systems.

Components of PBL+	Type of subject						Average for all the subject's types	
	Process engineering		Management and economy		Environmental engineering			
	Mixed system[2]	Entirely online	Mixed system[2]	Entirely online	Mixed system[2]	Entirely online	Mixed system[2]	Entirely online
PBL[1]	3	2	4	4	2	2	3.0	2.7
Flipped classroom	5	4	5	4	4	3	4.7	3.7
Service learning	2	1	3	2	3	1	2.7	1.3
Rubric for assessment	3	2	4	2	3	2	3.3	2.0
Average	3.3	2.3	4.0	3.0	3.0	2.0		

The assessment of suitability is arranged according to the type of subject (see Table 1 for more details). Values according to a Likert scale from 1 (minimum suitability) to 5 (maximum suitability) compared with the entirely face-to-face scenario before the pandemic COVID19.

[1] *in PBL+ the PBL requires direct contact with a commissioned person from the company*

[2] *mixed system is face-to-face and online simultaneously*

The obtained results indicate that PBL+ is severely affected by the waive of the face-to-face activity, because in most of the cases the suitability scores are 3 points or less out of a scale of 5 points. Interestingly, the type of subject affects only slightly to the suitability to the pandemic adaptations. Even with that, the management and economy subjects were slightly less affected than the purely engineering subjects, because for the last, a visit to the company is very important in order to understand the problem to be solved. Conversely, in the management or economy disciplines is easier to understand the problem by means of a visio conference.

From all the components, the service learning was the most severely affected. Some authors put forward the possibility of continuing with the social engagement through an enhanced electronic service-learning, which maximizes the human resources' capacity and highlights students' creativity with equally useful projects [16]. In our case, one of the options of service learning consists on the assistance to small florists to solve physiopathies or biotic stresses that produce severe economic losses to such a self-employed entrepreneur, that usually have not the necessary agronomic knowledge to solve that kind of problems. Moreover, such a small company do not have the possibility of paying for a consultancy and the suppliers usually do not provide that kind of after-sale service. Other kind of service-learning activity is the collaboration with urban agriculture experiences for retired persons, in the form of training activities to improve the environmental engagement of leisure farmers, and this activity is very reduced for the need of a social distancy, and thus this activity is also severely affected.

As a consequence of the changes in the activities, the rubric for assessment are outdated and it is not adequate for the proposed evaluation. To avoid this situation, it has been proposed to elaborate flexible e-rubrics online-offline [17].

Finally, the flipped classroom is the less affected component, and according to the surveyed teachers it is the most easily adapted to online teaching situations. Figure 3 shows in a colour code, the adaptation of the different components to mixed or entirely online teaching.
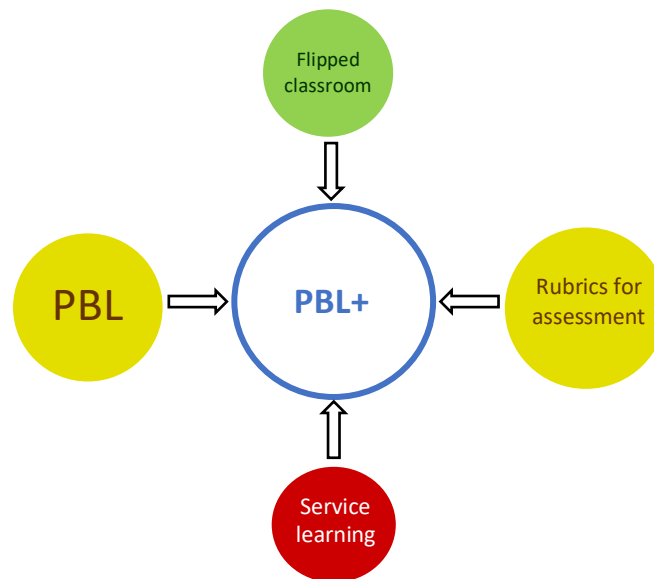
Figure 2. Components of the PBL+ and their suitability to mixed and online learning. In green colour the most suitable, in yellow intermediate suitability that need adaptations (see text for details) and in red colour no suitable.

3.2 Degree of achievement of the different competences covered by the PBL+ in mixed systems (face-to-face and online simultaneously) and entirely online systems

Tables 3 shows the degrees of achievement of the competences covered by PBL+ in mixed learning and entirely online.

Table 3. Degree of achievement of the different competences covered by the PBL+ in mixed systems (face-to-face and online simultaneously) and entirely online systems..

| Competence | Type of subject | | | | | | Average for all the subject's types | |
| | Process engineering | | Management and economy | | Environmental engineering | | | |
	Mixed[3]	Entirely online	Mixed[3]	Entirely online	Mixed[3]	Entirely online	Mixed[3]	Entirely online
Technical knowledge and skills	3	2	4	3	3	2	3.3	2.3
Synthesis capability	4	2	4	3	4	3	4.0	2.7
Critical thinking	3	2	3	2	3	2	3.0	2.0
Written communication skills	5	5	5	5	5	5	5.0	5.0
Oral communication skills	2	1	2	1	2	1	2.0	1.0
Average	3.4	2.4	3.6	2.8	3.4	2.6		

The assessment of the degree of achievement is arranged according to the type of subject (see Table 1 for more details). Values according to a Likert scale from 1 (minimum degree of achievement) to 5 (maximum degree of achievement) compared with the entirely face-to-face scenario before the pandemic COVID19

[2] mixed system is face-to-face and online simultaneously

The differences among the different types of subjects regarding the achievement of competences using PBL+ have been minimum. The competence more severely affected by the discontinuity of face-to-face activity was the oral communication skills, followed by the critical thinking. In both cases, the absence of a face-to-face debate and the substitution by online debate in which the students shelter behind a screen is, according to the surveyed teachers, a hindrance for the development of the competences. In third place, the technical knowledge and skills was also affected, especially in the engineering subjects, due to the absence of direct contact with the processes and the equipment involved in that processes.

By the other hand, the competences related with the personal study and work as the synthesis capability and written communication skills were less affected.

4 CONCLUSIONS

As a conclusion, the PBL+ has been designed to be used in face-to-face teaching systems, because the interaction between the students and the companies, which are their future employers, is a key aspect of the system. For technical and engineering disciplines, the visio conferences cannot replace the in-person exploration of the processes in which the problems to be solved are born. But not even in most of the management and economical subjects, the face-to-face interaction to understand the companies' problems can be fully replaced by a virtual communication, although they adapt better than the pure engineering disciplines.

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, with a suitability score for mixed learning of more than 4.5 and for entirely online of almost 4.

The rubrics results outdated as a consequence of the changes imposed by modification in the percentage of face-to-face or the shift to an entirely online model as a consequence of the pandemic evolution, and the option to solve this problem is the use of flexible rubrics.

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.

As a result of the assessment carried out, the training process of engineers, that will be on charge of productive processes and environmental infrastructures in the future, cannot be based on online learning-teaching systems. Moreover, the mixed systems should be kept to a minimum, and the PBL+ activity should be part of the face-to-face activity in mixed systems.

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