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CHOOSE YOUR PROBLEMS! A FLEXIBLE LEARNING METHODOLOGY FOR ENGINEERING STUDENTS BASED ON PBL+

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Abstract

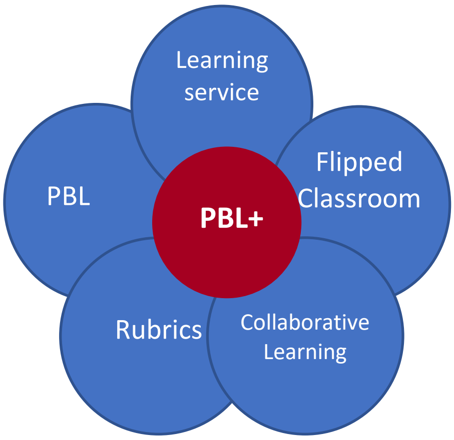
Problem Based Learning Plus (PBL+) is a teaching-learning methodology developed by the Teaching Innovation Group INGENIAQ from the University of León in Spain. It is designed for engineering students, including environmental and agricultural engineers, and also for biotechnologists specializing in production processes. PBL+ is based on the traditional PBL methodology, but with a wider aim. The proposed methodology combines three other teaching-learning methodologies, namely the flipped classroom; the use of rubrics for the evaluation of the activity; collaborative learning, and in some cases, the service-learning. This latter is understood as a service for microenterprises and self-employed workers. A relevant aspect is that students are free to choose the problem they will be working on, thus increasing motivation. The problem must be a real situation confronted by the company. Thus, students get in touch with a company having a close relationship with the subject topics and choose the case to be solved in a face-to-face meeting in conjunction with a company representative. In this way, students have an active role in defining the course's practical assignments. This flexible way of constructing their curriculum has proven to be motivating and it is an excellent strategy to approach real problems in their specialty. Moreover, the contact established between the University and enterprises is a valuable source of information for professors and students regarding current problems in the sector. Notwithstanding, not all engineering sectors are willing to share their issues with students. In this sense, the biotechnological industry is very reluctant to do so, whilst the agricultural sector is prone to it. In this work, we summarize the technical problems affecting the agricultural sector, tackled by the students after 4 years of PBL+ implementation. Sixty percent of the issues are related to phytosanitary topics, mainly emerging pests or diseases. This is a severe threat to the agricultural sector, and many small companies lack the technical knowledge necessary or experience in fighting plant diseases not previously suffered, asking for help to the University. The other 30% corresponds to alterations in crop growth due to abiotic factors. The remaining 10% consists of adapting productive processes to legislative changes.

Keywords: *Problem Based Learning, flipped classroom, flexible practices, rubrics, motivation.*

1. Introduction

The PBL+ is a teaching-learning methodology intended to immerse students in the business world (Urbano et al., 2020). This methodology is based on the classical Problem Based Learning but with a substantial change which is the direct interaction between students and a company so that the first ones solve a real problem faced by the company. Moreover, instead of selecting a company from a list proposed by the teacher, students are encouraged to search themselves and look for a company they can work with based on their interests. Students are also free to choose the problem among the several raised by the company (Urbano et al. 2022). For this reason, it is possible to say that students "choose their own problems". PBL+ includes other 4 learning-teaching strategies (Figure 1), namely: i) Flipped Learning because the activity starts at the very beginning of the course, to have enough time for the activity to be carried out and thus search for the theoretical knowledge needed to provide students with skills needed to solve it; ii) collaborative learning, because PBL+ includes at least two tutorships in the group, with the rest of the colleagues, so the work is subjected to peer review; iii) learning service in the cases in which students solve a problem from a microenterprise unable to access a consultancy for help — a very common situation in small agriculture companies — iv) the use of rubrics for evaluation because such an innovative activity needs evaluating guidance (Urbano et al., 2022).

Figure 1. PBL+ Components.



During the last four years, PBL+ has been used in 10 engineering subjects from three different knowledge areas, namely Biotechnology, Agronomy and Economy. The strengths and weaknesses related to the use of PBL+ in three model subjects, one from each of the three mentioned knowledge areas, were analyzed by Urbano et al. (2021), and a SWOT (strengths, weakness, opportunities and threats) analysis for each area was performed. According to that work, the teaching-learning process becomes more attractive with PBL+, being useful for the different knowledge areas that make up the engineer training. However, they found that some problems hinder the use of PBL+. Public information accessible in scientific databases is overly theoretical, and it is difficult for the students to distinguish that information useful for the industry from the pure theoretical musings.

In the present work, we analyze the application of PBL+ in the agriculture sector to fulfill the competencies of Agricultural Engineers. Specific aspects related to the use of PBL+ were evaluated in the Agrarian sector. Moreover, we summarize the type of problems considered more relevant that correspond to those proposed by the different companies students get in contact with.

2. Objectives

The objective of this work was to show the experience of using PBL+ in Agricultural Engineering subjects. The specific aims were:

1. To ascertain the impact of PBL+ in the improvement of the teaching-learning process of Agronomy subjects of the Agricultural Engineer curriculum
2. To summarize the most and less common problems raised by companies which can be solved by agronomic students

3. Methodology

3.1. Assessment of the impact of PBL+ in the teaching-learning process

The impact of PBL+ in the teaching-learning process was assessed by evaluating seven learning outcomes (see Table 1) in the "Crops Production Systems" course of the Master in Agricultural Engineering. An indicator was created for the verification of each learning outcome.

Table 1. Indicators used for evaluating learning outcomes with PBL+ for the "Crops Production Systems" course of the Master in Agricultural Engineering.

Learning outcome	Verification
Improvement of academic performance	Marks achieved by students in the evaluation process (using rubrics)
Students' motivation	Satisfaction survey applied to the students / Self-evaluation using rubric
Effective interaction between students and company	Number of contacts student – company representative
Development of autonomous learning	Evaluated by the average of the rubric items: quality of the literature used and technical quality
Critical thinking development	Survey applied to the teacher
Competences achievement (readiness of students to join the job market)	Survey applied to the company representative
Interaction between students and collaborative work	Average number of times that each student participates in the group tutorships/total number of students

The courses analyzed were those in the period 2017-2022, and one previous to incorporating PBL+. In the satisfaction survey applied to the students, the points evaluated were:

i) Rate from 1 to 5 the usefulness of entering into real contact with companies in the sector
ii) The evaluation of their own learning was assessed by the self-evaluation using rubrics

In the satisfaction survey applied to the teachers, they were asked about (rate 1 to 5):

i) The students' ability to search for the information needed to solve the problem in an autonomous way, and the quality of the information managed
ii) The students' achievement of critical thinking
iii) Other factors not related to the learning outcomes, for example, the company's willingness to collaborate and the alignment of PBL+

In the satisfaction survey applied to the company representative, the points evaluated (related to the achievement of the learning outcomes) were the following:

i) Readiness of students to join the job market
ii) Usefulness for the company of results obtained by students

3.2. Summary of the most and less common problems raised by companies which are to be solved by students

The problems solved by students during the courses previously indicated were compiled, classified and presented in table 2.

4. Results

4.1. Assessment of the impact of PBL+ in the teaching-learning process

The evaluation results of the seven learning outcomes considered are shown in Table 2. The course 2016-2017 corresponds to the year before using PBL+, and the mark included for that year corresponds to the practical activity before implanting PBL+. The period 2017-2018, was that where PBL+ was not fully established, i.e., there was no rubric for evaluation. The rubrics are delivered to the students at the kick-off session so that they know from the start the evaluating criteria and what is expected from the activity. It can be observed that the introduction of PBL+ without a rubric not only did not improve the marks achieved by students in the practical activities, but it was slightly lower. Moreover, in the absence of a rubric, the difference between marks obtained by students in the evaluation, and self-evaluation differs in more than 20%, indicating that students did not understand what it is expected from them. However, complete PBL+ (including rubrics) improved marks compared to the previous practical activity. In general terms, all learning outcomes improved when rubrics are introduced as a component of PBL+.

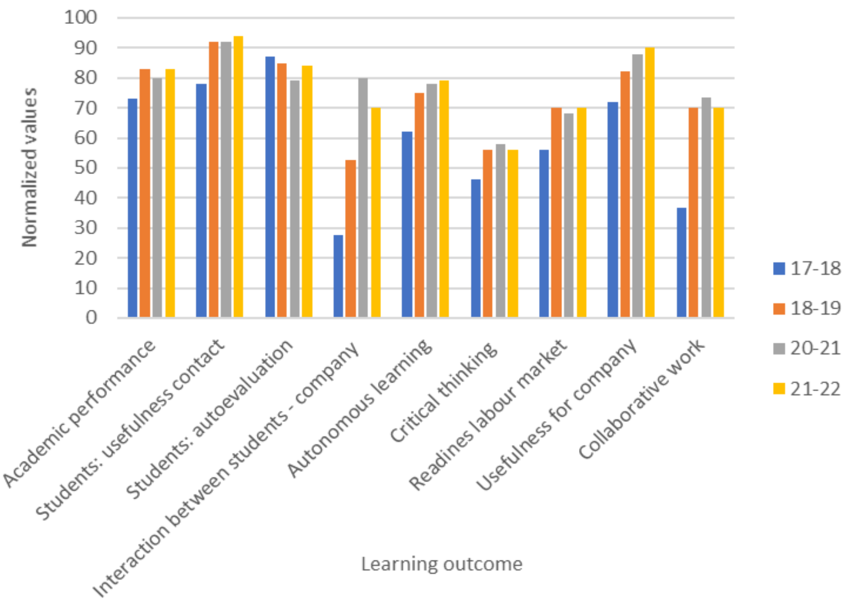
Figure 2 shows normalized values for the seven indicators of the learning outcomes performance. In general terms, after the rubric was included as a component of PBL+ (From 2018-2019 onwards), all indicators exceeded the value of 70 out of 100, except for the critical thinking, that in the opinion of the teacher, reached less than 60 out of 100 normalized points. Related to this parameter, the employer gave only a mark of 70 normalized points out of 100 about the readiness of the students to join the labor market. Incorporating a rubric improved the performance of all learning outcomes as already stated, except for self-evaluation, indicating that the absence of clear criteria favors misleading and false optimistic feeling about their own learning.

*Table 2. Absolute values obtained for indicators used to evaluate learning outcomes with PBL+ for the "Crops Production Systems" course of the Master in Agricultural Engineering. Four years were considered (2017-2022) while for 2016-2017 practical activities were based on the resolution of a theoretical problem in the classroom. Values represent averages and number in parenthesis are the variation coefficient (standard deviation/average value)*100.*

Learning outcome	Verification	Range	Year				
			16-17 (before PBL+)	17-18 (PBL+ no rubric)	18-19	20-21	21-22
Improvement of academic performance	Student marks achieved in the evaluation process (using rubrics)	0-10	7.4 (±22%)	7.3 (±20%)	8.3 (±25%)	8.0 (±28%)	8.3 (±25%)
Students' motivation	Survey: Usefulness of getting in contact with companies of the industrial sector	1-5	-	3.9 (±6%)	4.6 (±8%)	4.6 (±9%)	4.7 (±7%)
	Self-evaluation using rubrics	0-10	-	8.7 (±12%)	8.5 (±20%)	7.9 (±25%)	8.4 (±18%)
Effective interaction between students and company	Number of contacts student-company representative	0 - ∞	-	1.1 (±5%)	2.1 (±10%)	3.2 (±15%)	2.8 (±12%)
Development of autonomous learning	Evaluated by the average of rubric items: quality of the literature used and technical quality	0-10	-	6.2 (±26%)	7.5 (±16%)	7.8 (±24%)	7.9 (±21%)
Critical thinking development	Survey applied to the teacher [1]	1-5	-	2.3	2.8	2.9	2.8
Competences achievement (related to integration in professional activity)	Survey applied to the company: Readiness of students to join the job market	1-5	-	2.8 (±11%)	3.5 (±9%)	3.4 (±12%)	3.5 (±14%)
	Survey applied to company: Usefulness of results obtained by the students	1-5	-	3.6 (±21%)	4.1 (±28%)	4.4 (±19%)	4.5 (±33%)
Interaction between students and collaborative work	Average number of times that each student participate in the group tutorships/total number of students	0 - ∞	-	1.1 (±22%)	2.1 (±32%)	2.2 (±28%)	2.1 (±20%)

[1]There was no dispersion measurement because there was only one teacher

Figure 2. Normalized values (0-100) obtained for indicators used to evaluate learning outcomes with PBL+ for the "Crops Production Systems" course of the Master in Agricultural Engineering. Normalized values are relatives to the maximum possible score (5 or 10 as corresponds) except for the "number of interaction student-company" and "number of times that each student participates in the group tutorship" in which values were relativized to the value that was considered as optimum (4 and 3 respectively).



4.2. The most and the less common problems raised by the companies which are to be solved by the students

Interestingly (see Table 3), the agronomic problems that concern farmers more often are those related to phytosanitary or physiopathy issues, whilst issues related to the environmental performance of agriculture, e.g. biodiversity improvement, microbiological soil activity, etc. not even appear mentioned.

Table 3. Indicators used for evaluating learning outcomes in PBL+ application for Agronomy subjects in Agricultural Engineer studies.

Type of problem	Details (wherever necessary)	Number of works	Percentage
Phytosanitary issues	Emerging plague or diseases	8	28%
	Development of resistances to classical treatments	9	31%
Physiopathies from unknown but not-biotic origin		6	21%
Weeds control	Due to the appearance of resistance to classical treatments	2	7%
Adaptation of productive practices to new regulations	Reduction of acrylamide contents in potato chips that involves changes in potato production process	1	3%
Transformation to organic production		1	3%
Other agronomic problems	Includes the distribution of the plots (pollination problems due to the distribution of pollinators in the plot); irrigation and fertilization management	2	7%

5. Conclusions

The use of PBL+ in the course “Crops Production Systems” gave good values for the learning outcomes considered. One of the components, namely the use of rubrics, was critical to obtaining good performance. The reason is that rubrics help students to focus their work on relevant aspects closely related with competencies to be achieved. Critical thinking continues to be the most challenging competence to be attained. The main concerns of Agrarian businessmen keep relation with phytosanitary or physiopathy issues. The results obtained can be extrapolated to other subjects related to the curriculum of Agricultural Engineers, especially those associated with Agronomy.

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