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Multidisciplinary Education for New Landscape Engineering Concepts using Problem-Based Collaborative Learning. A Case Study in Spain*

L. PÉREZ URRESTARAZU
Department of Aerospatiale Engineering and Fluids Dynamics, University of Seville, EUITA, Ctra. Utrera, km 1. 41013 Seville, Spain. E-mail: lperez@us.es

A. FRANCO SALAS
Department of Aerospatiale Engineering and Fluids Dynamics, University of Seville, EUITA, Ctra. Utrera, km 1. 41013 Seville, Spain. E-mail: afranco@us.es

R. FERNÁNDEZ CAÑERO
Department of Agroforestry Sciences, University of Seville, EUITA, Ctra. Utrera, km 1. 41013 Seville, Spain. E-mail: rafafc@us.es

Problem-based learning (PBL) is widely regarded as a successful educational method. In Spain, most engineering degrees are still based mainly on old style lecture classes where a great deal of information is given to the students. This work assesses the introduction of a PBL strategy as a complement to traditional engineering education. The instructors' and students' attitudes towards its implementation are studied. A new approach has been proposed for the PBL strategy: instead of a single problem, a chain of problems was developed that could be solved in a collaborative environment. Results from the experience showed a high level of student acceptance. Response to the PBL initiative was found to be positive both for instructors and students, though lack of time, difficulties in evaluations and an increase in students' and teachers' workloads were the main disadvantages. Compared with traditional engineering curricula, the mixed traditional–PBL model appears to inspire a higher degree of involvement in study activities where on-line learning tools played an important role.

Keywords: PBL; collaborative learning; multidisciplinary education

1. Introduction

Engineering education is nowadays rapidly evolving towards a practical oriented education where the student's own work takes on a greater importance. In Spain, most engineering degrees are still based mainly on old style lecture classes where a great deal of information is given to the students. The implementation of the forthcoming Bologna agreement [1, 2] intends to change these concepts and takes student homework into account.

Engineering educators are concerned with how the students approach their own learning: many educators think that students are trained to be passive, so an environment that allows educators to tackle problem-solving concerns should be provided [3]. The overloaded content of engineering courses leads many students to take an instrumental approach, characterised by the motivation to pass exams rather than being driven by an interest in learning [4]. The motivation to learn affects the amount of time that students are willing to devote to learning and it increases when they can understand the usefulness of what they are learning [5]. This is a reason for developing techniques such as problem-based learning (PBL) and case-based teaching, which use professionally relevant real situations and problems to provide contexts for learning contents and skills [6].

1.1. Problem-based learning: a well-known methodology

Challenges can provide a context for knowledge, which can facilitate a student's application of this information in future situations [7]. When concepts and ideas are presented to learners outside a specific context, the students have no way of associating this knowledge with the tasks that they may have to solve in the future [8].

The PBL approach was introduced by Barrows [9] in medical teaching but it has been adopted in other fields, including many applications in engineering [10–16].

The performance requirements of the tasks in the PBL class are meant to replicate those of the real world. Therefore, a primary goal for educators is to create a situation where the skills (know-how) and knowledge (know-what) that is experienced in the class is analogous to that learned in the real world [17].

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Therefore, PBL is perfect for engineering education as it encourages a multi-disciplinary approach to problem solving (which is essential in modern engineering practice) and develops techniques and confidence in solving problems that have not been encountered before. In addition, by incorporating small group cooperative learning, students are able to maximize their own and other group members' learning by working in teams to accomplish a common task or goal [18].

1.2 Collaborative learning: working in groups

It is known that learning in small groups is effective in enhancing student performance and attitudes toward learning [19, 20]. Implementations of inductive approaches such as PBL normally involve active and collaborative learning methods [21], which some suggest are more beneficial than competitive learning [22]. A cooperative structure is defined as that where every group member is rewarded on the basis of the quality of the group's product. However, cooperative and competitive efforts have different impacts on problem solving according to the type of problem presented [23].

Collaborative learning implies that knowledge is generated as it is shared and reinforced through group-based discussions [24]. Interaction exists between students when they orally explain to each other how to solve the problem, discuss the nature of the concepts and strategies being learned, and impart their knowledge to classmates [25].

1.3 PBL vs. lecture-based teaching

A lecture to a classroom of students is probably the most common form of 'information transfer' used in teaching at university level. This method puts pressure on both the professors administering the lectures as well as the students who are forced to identify and process important concepts in the presentations. On the other hand, collaborative learning removes the professor as the so-called expert on the course material and empowers students with control of their own understanding of both basic and advanced concepts [26].

The traditional lecture-based approach is commonly accepted as the most efficient way of conveying the large amount of information that students will need to become proficient in the subject matter [27]. Nevertheless, some studies indicate that students taking courses taught using active and collaborative approaches such as PBL reported significant advantages in a variety of learning outcome areas (specially in communication, design and group skills) when compared with those enrolled in conventionally taught courses [28, 29]. Lecture-oriented teaching and PBL methodologies have different effects on the success rate of students with dissimilar learning preferences [30]. Students appear to have an especially hard time with the prevailing lecturing environment found in engineering classes but they thrive in situations where divergent thinking, innovation, and subjective interpretations are encouraged [31].

1.4 Objectives

This study tries to address the following questions.

- What is the result of introducing an optional inductive learning (PBL methods) into a traditional lecture-based course?
- What are the main concerns of instructors in implementing PBL techniques?
- What is the student response and attitude to the changes in teaching procedures?

2. Methodology and course structure

In order to assess the viability of including PBL methodologies in some Agricultural Engineering courses (University of Seville, Spain), a joint project was developed with the support of the Learning Science Institute during the 2007–08, 2008–09 and 2009–10 academic years. Given that the main problems stayed within the introduction section, a mixed lecture–PBL strategy was used. Two different courses were involved in the initiative: Hydraulics and Irrigation and Gardening Technology, with students from these courses participating.

Students had two options: they could just attend the traditional classes or, in addition, they could participate in the PBL proposal. Basic information and general concepts were explained in lecture-based classes that included all the students of the courses involved. Afterwards, the students who were involved in the PBL initiative were presented with a general problem: to provide 'Engineering' solutions for urban sustainability from an environmental and landscape perspective'. They had to propose multiple solutions for this open problem and then develop and design the best option.

The students were divided into groups and each student had to develop a solution, and present it for discussion. From these, the best alternative was selected, which then becomes the new problem. Once again the teams work at designing options and analysing the advantages and disadvantages of the other groups' solutions. When the best solution has been chosen, the cycle starts again, becoming a Problem Based Learning Chain (PBLC) (Fig. 1). In each step of the process, one member of the group becomes the leader whose task is to coordi-

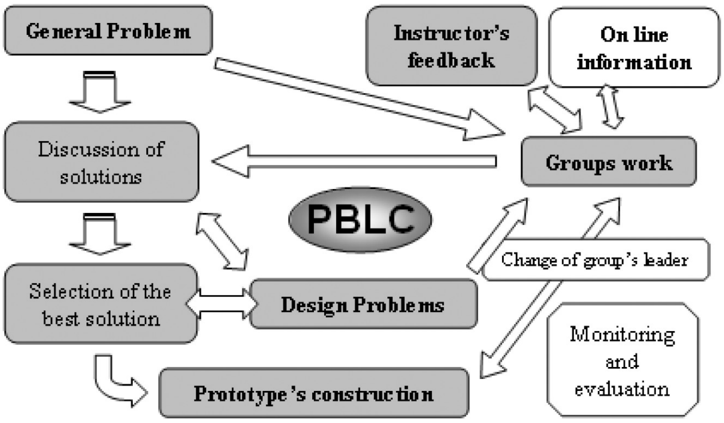

Fig. 1. Methodology for the Problem-Based Learning Chain.

nate the views of the other members and to make the final decision.

There are many benefits to engaging students in a cooperative learning group activity organized within a competitive setting [32]; in this case the best problem solution was authorized to be carried out and the team given an award in order to create a slightly competitive environment and encourage interest. Therefore when the selected solution is well defined and designed the teams are encouraged to execute the project and evaluate the result, comparing it with the other possible solutions.

The amount of information that graduates need to acquire is increasing and continuously changing and less time is available for the instructor to present it, so online support is needed [33]. In our PBLC initiative, the students counted on the backing and guidance through OCW (OpenCourseWare) [34] and WebCT (Web Course Tools) [35, 36], where the instructors added information, examples and procedures and the teams' were assisted with their work and supervised. Given that not much time was available for class discussions, an online forum was also used where students and instructors debated the different problems and solutions.

Identifying task relevant information in an engineering problem solving environment is a critical step in the problem solving process [37]. Moreover, students were found to have less experience of searching the Internet to find technical information than was expected and they did not use supplementary information such as tutorials unless they needed to use the material [38]. Therefore, students were committed to searching, preparing and bringing this type of material to the class in order to have background to discuss and look for the problem solution.

Students participating in PBLC procedures were evaluated using the same exam as 'traditional students' in order to facilitate the comparison of the knowledge and skills acquired in each case. In addition they carried out a peer assessment. In order to study the viability and results of the implementation of these techniques, surveys that were addressed to instructors and students were used.

3. Results and discussion

3.1 Methodology implementation

In addition to traditional lecture classes, students were offered the possibility of participating in the PBLC initiative. For this, four sessions were assigned to studying and discussing the proposed solutions. Throughout the process, information (articles, news, and web pages) was provided online for students and an open debate between groups was monitored by the instructors. Fifty-two students agreed to follow the PBLC proposal and three rounds of the cycle (several solutions—selection of the best—new problem) were necessary in order to reach the best option.

The problems presented to the students were relatively open-ended, thus allowing for divergent and creative options. From all the solutions given by the different groups, an urban greening project was selected as the best. This is one of the most interesting applications of Landscaping Engineering and demands a multidisciplinary approach. Owing to its innovative nature, the students showed a high level of motivation during their participation in the different stages of the project. As a result, a vertical garden involving all the students participating in the PBLC initiative was constructed. As different aspects were involved in carrying out the solution project, students following the Gardening Technology course worked on the 'biological design', while students enrolled in the Hydraulics and Irrigation course were responsible for the irrigation engineering design.

Students were encouraged to provide feedback during sessions. Group reports of the main problems faced and procedures and solutions arrived at were produced in order to provide first hand information to future students.

This initiative also introduced students to further research techniques and design methodologies in addition to the knowledge usually gained in traditionally courses. Because of this, students were encouraged to construct prototypes of the vertical garden that was proposed as the solution to the problem. In addition, the prototypes were used in other courses to study their performance and monitor several parameters such as temperatures, humidity, radiation etc. Different tests and experiments were also carried out after the prototypes had been completed. These led to visual aspects and comfort issues becoming part of some students' degree theses.

Some difficulties were faced when trying to implement the PBL strategy, such as how to react when students do not keep to the deadlines for presenting solutions or how actually to calibrate students' work in each activity. For the latter, peer assessment was included in the methodology in addition to traditional evaluation by instructors. Though the teachers reported that it provided valuable information, not all the students agreed with their companion's decisions.

3.3 Evaluation, student attendance and participation

In most Spanish universities there are some additional problems that affect the applicability of these types of methodologies, such as a very poor class attendance and a lack of motivation. In addition, a large number of students are working, so in spite of their practical background they are not able to attend all the classes. Therefore these teaching methods could be part of the solution if the learning process is approached differently, allowing distance or blended learning to take place.

Nearly all the students participating in the PBLC initiative went to all the classes (93% attendance) while the rest of the students showed a much lower percentage (56%). Furthermore, the keeping of office hours by the students increased by 43% when following the PBLC option. These numbers lead one to think that students were much more interested in attending the classes with the mixed PBL–traditional teaching. Other studies in Spain also showed an increase in motivation when using these strategies [39, 40].

In order to evaluate the results of the activity, different methods were used. Each stage of the project was assessed and monitored in terms of applicability, design and students' participation. The final evaluation was conducted both qualitatively and quantitatively using questionnaires. The students were also encouraged to conduct peer assessments to evaluate their participation in finding the solution. In addition, students participating in the PBL initiative took the traditional exam in order to compare their results with those of the rest of students.

Other authors have stated that results from the evaluations showed a better performance and an increase in knowledge in students in Spanish universities [41, 42], as well as those in other countries [43], who followed PBL strategies. In our case, the marks of PBL students ranged between 3.1 and 10 points (on a scale of 0 to 10) with an average of 6.88. Traditional students who were graded from 4 to 9 showing a slightly lower average mark: 6.39. With these results it is difficult to claim that PBL students learned more. Nevertheless, a greater difference was seen in exam attendance. Only 65.4 % of traditional students took the exam, while 87.5 % of PBL students took

Table 1. Problems when using a PBL methodology: Question 1 Which problems will you face when using a PBL methodology?

	Students		**Instructors**		**ET**[a]
	μ	σ	μ	σ	
Lack of time to teach all the course topics	3.10	1.071	3.39	1.283	
The need for teaching basic concepts prior to practical knowledge	3.38	1.069	3.20	1.270	
Difficulties in knowledge evaluation	2.90	0.891	2.72	1.099	
The student/instructors' work increases	4.35	0.947	4.13	1.008	
Poor class attendance	2.08	1.234	3.17	1.262	A
Absence of student motivation	2.15	1.109	3.27	1.202	A
Low student participation	2.00	0.99	3.17	1.315	K
Decrease in theoretical knowledge levels	2.21	0.997	2.62	1.147	
Difficulties due to working in groups	3.35	1.083	3.07	0.961	
Students problems to search and select information	2.67	1.052	3.20	1.349	K

[a] Equality test (ET): difference in means between students and instructor responses statistically significant ($p < 0.05$) in one-way ANOVA test (A) or Kruskal–Wallis test (K)

Table 2. Advantages of the PBL methodology: Question 2 PBL methodology's advantages over traditional teaching techniques

	Students		Instructors	
	μ	σ	μ	σ
Encourages students to work in groups	4.35	0.814	4.61	0.495
Provides a practical background	4.27	0.598	4.19	0.833
Students teach and learn from each other	4.06	0.938	3.81	1.078
Analysis and problem resolution skills are enhanced	3.90	0.878	4.06	0.964
Students improve their communication skills	4.04	0.685	4.16	0.779
Students develop a project-design attitude	4.19	0.687	3.97	0.983
Increases students' motivation	3.87	0.841	3.77	1.023

Table 3. Problems when using a PBL methodology. Question 3 Which elements would be necessary to implement a PBL methodology?

	Students		Instructors		ET[a]
	μ	σ	μ	σ	
Audiovisual resources	4.02	0.761	3.20	1.324	K
Computer tools	4.17	0.678	3.77	1.073	
Virtual learning tools and on-line network platforms	3.83	1.115	3.47	1.106	
Courses with fewer students	3.46	1.179	4.19	1.138	A
More instructors	2.94	0.938	3.9	1.213	A
Instructors' training in PBL techniques	3.67	0.923	4.55	0.624	A
Students prior preparation (basic knowledge, information search techniques, etc.)	3.81	0.864	4.03	0.964	
Incentives for instructors	3.84	0.946	4.27	0.980	K

[a] Equality test (ET): difference in means between students and instructor responses statistically significant ($p < 0.05$) in one-way ANOVA test (A) or Kruskal–Wallis test (K)

it. This can be explained by the fact that students who took the PBL option felt more prepared and self-confident, whereas many traditional students thought they were not yet ready. Of the students taking the exam, 69.6% of traditionally taught students passed the exam while 79.7% of PBL students did it.

3.3 Students and instructors' perceptions

Once the PBLC initiative was over, students were asked to fill in a survey in order to ascertain their opinions of the difficulties they faced and the advantages they gained. Several questions were presented to the students and different options were available. Each option had to be rated following a Likert scale as follows: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree. Similarly, another survey was taken in order to gain an insight into the instructors' points of view of the advantages, problems and requirements involving a PBL strategy. Therefore, an on-line questionnaire was compiled, which was answered by thirty-one instructors. Tables 1 to 4 illustrate the mean value (μ) and standard deviation (σ) for each alternative and the difference in means between students' and instructors' responses.

As other authors discuss [44], unfortunately many instructors argue that much time is lost in the implementation of the PBL approach and many critical topics relevant to the engineering practice risk of not being covered [45]. In this study, both students and teachers think that the main problem is the increase in workload (Table 1), so more time will be necessary to carry on with these procedures. Also, basic concepts are required to be covered prior to the practical knowledge, due to the lack of time for teaching all the course topics. Students were also concerned with the difficulties encountered when working in groups. Both collectives consider that there will be no decrease in theoretical knowledge levels. In the topics involving student motivation and participation, students found no problem, while instructors were more concerned.

No differences in opinion were found in relation to the advantages of PBL techniques (Table 2). The most valued benefits are the practical background provided and the encouragement to work in groups, while the increase of students' motivation was rated less highly. Table 3 shows that instructors find a prior training in PBL techniques essential, and more teachers and incentives were needed. Also, the excessive number of students in the course groups becomes a challenge as instructors need much more time and effort to give some guidance and to monitor the students' improvements. In addition, as the students have a huge

Table 4. Implementing a PBL methodology. Question 4 How would you implement a PBL methodology?

	Students %	**Instructors** %
I would only use the PBL methodology	9.6	6.5
I would combine PBL and traditional lecture-based teaching	78.8	77.4
I would continue with lecture-based teaching and use PBL with on-line learning	9.6	6.5
PBL would be optional for the student	1.9	6.5
I will never use PBL strategies	0	3.2

Table 5. Students' overall opinion (%)

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I consider that the PBLC initiative accomplished was positive	1.9	2.3	24.6	40.4	30.8
I think peer assessment is adequate	13.5	11.5	21.2	42.3	11.5

difference in knowledge levels (some of them have not passed previous courses), it is difficult to put together equitable groups. On the other hand, students give more importance to computer and audiovisual resources and virtual learning tools. On-line tools were widely used in this experience and the forum was the main channel for the discussion of solutions.

Nearly 80% of students and instructors would combine PBL strategies with traditional lectured classes (Table 4). All students are convinced about following any kind of PBL methodology but a few instructors would never use it.

Some ANOVA tests were run in order to study if the respondents' characteristics (gender, age, number of years teaching or studying, academic status) influenced the replies. None of them was significant except for the instructors' gender. Female instructors demonstrated much higher concern in audiovisual resources and on-line learning platforms as key tools for PBL strategies than their male colleagues.

Finally, students were asked about their overall opinion about the accomplished PBLC initiative and the evaluation strategy used (Table 5). More than 70% of students considered that the PBLC initiative was positive and less than 5% disagreed. This is consistent with other experiences of PBL applications in Spanish universities where students believed that they gained a valuable knowledge that was especially practical [39, 42]. The adequacy of peer assessment as an evaluation method was supported by 50% of students but 25% of them did not share this opinion.

3.4 Limitations

Like any piece of social science research, the findings in this study are subject to some constraints since part of the survey relies on survey responses and opinions. As students were free to choose between traditional learning and the PBL initiative, the results may be distorted because good students (or more interested students) were more likely to select the PBL option. Therefore, as only the students involved in the PBL strategy filled in the questionnaire, some of their responses could be conditioned. The instructors' points of view can also be limited because none of them, except for the authors of this work, has carried out a PBL initiative. So their responses would only be based on assumptions and not on experience. However, these opinions are valuable as they might represent the concerns of the actors involved in the learning process.

5. Conclusions

After analysing the results of the initiative it can be concluded that it was very satisfactory both for the students and the academic staff. Compared with traditional engineering curricula, the PBL model showed a higher degree of student involvement as their attendance at classes and the time devoted to the learning process were much greater.

Most instructors interviewed would use a mixed PBL–traditional strategy, though the high number of students per teacher and the volume of work generated appear to be the main limitations. On-line learning tools were highly used and they played an important role in providing information, also becoming the main discussion channel.

The evaluation results showed that problem-based learning can be a valuable tool to complement traditional teaching methods. Though the average mark was slightly higher, the attendance at classes and exams significantly increased in the case of the PBL option. Moreover, when this methodology is oriented to innovating issues such as those presented, the instructors observed that students are highly motivated and easily get involved in the learning process with less effort.

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Luis Pérez Urrestarazu is an associate professor at Seville University (Spain) teaching Hydraulics and Irrigation and Greenhouse Technology at the School of Agronomic Engineers. He is an Agricultural Engineer (2003) and Advanced Technician in Occupational Risks Prevention. He gained his European Ph.D. (2008) at Cordoba University. He was a research fellow at Cordoba University where continues to contribute as a member of the Research Group of Hydraulics and Irrigation (AGR 124). He is involved in a number of research and learning projects dealing with irrigation and water management and also with Urban Greening issues. He has done postdoctoral research at Wageningen University, Cranfield University and Loughborough University.

Antonio Franco Salas is an assistant professor at Seville University (Spain) teaching Hydraulics and Irrigation, Greenhouse Technology and Engineering Projects at the School of Agronomic Engineers. He is an Agricultural engineer and he is studying for his Ph.D. at Almeria University following the Environment Engineering programme. Franco's research focuses on greenhouse cooling systems and he is part of the Research Group of Rural Engineering (AGR 198).

Rafael Fernández Cañero is a lecturer at Seville University (Spain) teaching Gardening Technology at the School of Agricultural Engineers. He is an Agricultural Engineer and he is studying Urban Greening Technologies for his Ph.D. at Seville University. He did a research stay in Swedish University of Agricultural Sciences, Alnarp (Sweden).