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An interdisciplinary complex problem as a starting point for learning: Impact of the PBL method in second-year Environmental engineering students

E. Sáez de Cámara[1]*, A. Lopez-Urionabarrenechea[1], M.N. Azpiazu[1], P. Ruiz de Arbulo[2], G. Insunza[2]

Faculty of Engineering, University of the Basque Country UPV/EHU
(1) Department of Chemical and Environmental Engineering
(2) Department of Business Administration
Alameda de Urquijo s/n, 48013 Bilbao, Spain

* Corresponding author: Email: estibaliz.saezdecamara@ehu.eus; Phone: + 34 946018212

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Abstract
Three courses of the second year degree in Environmental Engineering (Geology and Pedology, Ecology and Economics and Business Administration) have been remodeled using the Problem-Based Learning methodology. The proposed problem is a real-life and integrative problem related to their specialization which must be solved in these three courses at the same time. The results reveal that during this experience students were considerably more active, cooperative and involved, and the success rate doubled that of similar engineering courses of the Faculty. Regarding students' opinion, it should be emphasized that they perceive that this method is functional and encouraging. A high percentage of the students describe the experience as *positive* or *very positive*. Additionally, they stated that the Problem-Based Learning promoted the development of skills that, in their own view, are essential for their career, such as teamwork and communication.

Keywords
Problem-Based Learning; Environmental Engineering; interdisciplinary approach; life-long learning; intrinsic motivation.

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1. Introduction

Higher education in Environmental Engineering was implemented in Spain in 2011 (Ministerio de Educación, Cultura y Deporte, 2011), at the same time as the modification in curricula for harmonization with the European Education system. Until 2011, the engineering solutions applied to pollution-related problems were designed by civil engineers, industrial engineers, forest engineers, chemists or biologists, leading to partial solutions focused on their respective field of knowledge. Therefore, the reason behind the implementation of the new Bachelor`s degree in Environmental Engineering was to train engineers with an integrated view of the environment, able to address complex environmental problems: environmental impacts of population growth, resource depletion, climate change, water scarcity and the fate and hazards associated with pollutants, among others.

The degree in Environmental Engineering at the Faculty of Engineering of Bilbao of the University of the Basque Country (UPV/EHU) implies four years of study to obtain the Bachelor qualification. In the first two years students learn core fundamental sciences (such as Chemistry, Physics, Mathematics, Mechanics, Thermodynamics, Geology, Ecology, and Business), some of them together with the students of some of the other degrees awarded at the Faculty: Industrial Technology Engineering and Industrial Organization Engineering. Conversely, the last two years are devoted to the application of scientific knowledge to solve practical problems, especially in industry. This structure, quite similar to the pre-Bologna process one, leads to (I) unmotivated first and second year-students, which results in high dropout rates, and (II) severe difficulties to integrate theory and practice in the third and fourth year-courses as well as in their future career.

Furthermore, the results of surveys of industry perceptions of engineering graduates of how well they were prepared for work showed gaps in other attributes that play an important role in effective performance in the workplace: communication and teamwork skills together with broad perspective of other disciplines (Markes, 2006; Crawley et al.,

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2007; Richter, 2009). The last attribute, a holistic and an integrative approach, is essential in for our graduates since Environmental Engineering is defined as that branch of engineering concerned with the application of scientific and engineering principles for (I) the protection of human populations from the effects of adverse environmental factors, (II) protection of environments, both local and global from the potentially deleterious effects of natural and human activities and (III) improvement of environmental quality (AAEE, 2008; ABET, 2013).

Introducing and integrating these non-technical aspects in engineering education is not an easy task. Innovative approaches based on active and cooperative methodologies can provide a solution to the abovementioned challenges. Worldwide, an increasing number of institutions have changed, or they are in the process of changing, from traditional learning-teaching methods and moving towards these kind of approaches, as it has been demonstrated that they are more effective making graduates critical thinkers, problem solvers, life-long learners, effective communicators, team player and technically skilled. According to Kolmos (1996), Hmelo-Silver (2004) and Walker and Leary (2009), the main advantages of using innovative methodologies are: 1) increase of the student's intrinsic motivation, interest and implication, 2) reduction of the time to finish the bachelor degrees and a lower dropout rate, 3) augment of the ability to memorize concepts and apply the acquired knowledge, 4) development and strengthening of professional skills and 5) amplification of the capability to connect theory and practice.

Taking into account that such advantages cover the gaps identified in students of the degree in Environmental Engineering, an innovative and collaborative approach, Problem-Based Learning (PBL) methodology, was designed and implemented in three courses of these new degree. The PBL method uses relevant problems presented at the beginning of the learning cycle and, employed to provide the context of the courses. Together with the development of the curricula of the courses, the students, working in teams, go solving the problem by means of the application of theory, which concerns the

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student about the direct relationship between the course and the real-life applications. Teachers act as coaches and facilitators throughout the learning cycle.

Although the PBL evolved from Medical Education, it is regarded by some experts as the most suitable active and cooperative methodology for the simulation of tasks that are as close as possible to those carried out by engineers in their practice (Kolmos, 1996; De Graaf and Kolmos, 2003; Mills and Treagust, 2003).

The PBL experiment presented in this paper was designed and applied to three courses during the academic year 2013/14 in order to reduce the dropout rates of the first courses of the degree in Environmental Engineering, to increase the student's implication and motivation, and to prepare the future graduates for research and for employment in industry by developing the inherent skills of the Environmental Engineers. It is divided into five main sections. Section 2 provides a brief overview of the methodology. Students' opinions and academic results are presented in Section 3. Finally, Section 5 summarizes the results and discusses the avenues for the future.

2. Proposed methodology: Problem Based Learning

Three courses of the 2nd semester of the 2nd year of the degree in Environmental Engineering (Geology and Pedology, Ecology and Economics and Business Administration) were remodeled in the academic year 2013/2014 using the innovative PBL approach. An additional originality of our work lies on the fact that the PBL was applied simultaneously in these three dissimilar courses, since the problem to be solved was the same for the three of them and students need concepts and skills which are developed in these three courses in order to solve entirely the problem.

For this to be possible, a real-life and integrative problem related to their specialization was proposed. Additionally, we formulated a contemporary problem close to real life, for the purpose of helping students to see the connections between the academic environment

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and the real world. In particular, the dilemma was the selection of the most appropriate solution for managing and treating the organic fraction of the urban waste generated by a community. The proposal, presented Figure 1, was a complex and open-ended problem. The students, working in small teams, had to choose and select, and then justify, the most appropriate solution.

> "_____ is a graduate in Environmental Engineering and an advisor for the City Hall since a few years ago. In this town, as a result of the construction and occupation of new single-family houses, the Municipal Solid Waste (MSW) production rate has grown exponentially in the last ten years. Since the landfill where they are actually dumped is exhausting its usable life and it will have to be closed in a short term and, at the same time with the aim of advancing towards the goals marked by the European legislation, different options are being considered for the treatment of the most abundant fraction in the MSW: the organic matter. The City Hall has several parcels of land that could be used for the construction of these treatment facilities. These parcels were acquired in 2007 to build an incineration plant and the auxiliary structures, but the pressure of the activists of several platforms and the neighbors' rejection stopped the project.
>
> In the plenary session of the past 22 of January the council decided to ask the advisor _____ to analyze the technical, legal, social and economic viability of this solution, the measures and resources necessary to carry it out and to match the benefits compared with actual wastes management. The study should include a brief processes and installation descriptions, and a tentative target of economic analysis.
>
> In order to do so, the advisor will have access to all available information regarding this issue as well as to all necessary resources. The advisor _____ has three months to elaborate the document, which will be presented in the City Hall meeting the first fortnight of May"

Figure 1. The problem proposed to Environmental Engineering second-year students as a starting point for learning

This macro problem was divided into a number of partial problems dealing with contents, topics and methods of the three courses involved: (1) through the knowledge of Geology and Pedology's concepts and calculations, students had to choose the most suitable plot to carry out the treatment process; (2) through the knowledge of Ecology's concepts and calculations, students had to described the selected waste decomposition process; and (3)

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through the knowledge of Economics and Business Administration's concepts and calculations, students had to make an economic balance of the selected solution. Both, the macro problem and the partial problems, were specifically selected and edited to meet the educational learning outcomes, competencies and criteria of these three 6-ECTS compulsory courses.

As most of the students had no previous PBL experience, the learning process also concerned a series of activities related to introduce concepts and techniques. As recommended by experts (Felder and Brent, 1994; De Graaf and Christensen, 2004; Hmelo-Silver, 2004; Borrego and Newswander, 2007), activities involved understanding, research, decision-making and writing. Figure 2 shows three examples, one of each course.

Economy and Business Administration	The Balance Sheet by EKIN S.A. in December 31, 2013 shows the following elements.
	ASSETS LIABILITY
	Building……..100.000 €
	Building´s accumulated amortization...…… (30.000 €)
	Customers……...5.000 €
	Banks……..……..20.000 €
	Cash..……..5.000 €
	Equity……..…….50.000 €
	Long Term debt……..……..30.000 €
	Short term debt……..……...20.000 €
	
	During 2014 EKIN S.A. has carried out the following transactions.
	• In January the first, EKIN S.A. bought a van worth 15.000 €. It´s estimated life is 10 years and it´s residual vale 1.000 €. (paid through bank account)
	• The services offered by EKIN S.A. during 2014 were worth 65.000 €, from which 50.000 € were collected through the bank account, leaving the rest for future payment.
	• During 2014 EKIN S.A. faced the following expenses:
	  • Salaries: 40.000 € (paid through bank account)
	  • Combustibles: 1.500 € (paid through bank account)
	  • Insurances: 2.000 € (paid through bank account)
	  • Office materials: 500 € (paid through bank account)
	a) What´s the amortization rate for the van?
	b) Build up the profit and loss account for period 2014-2015
	c) Build up the Balance Sheet for period 2014-2015

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Ecology	Decomposition process a) Taking into account the availability of oxygen, how many types of decomposition processes are there? Describe their main stages. b) What are the main organisms involved in decomposition? Does it depend on the decomposition process? Give an example of a decomposer organism. c) What are the main chemicals released during decomposition? Does it depend on the decomposition process? Provide the chemical names and the state (gas, liquid, solid, and dissolved) d) What are the main differences between the natural (ecological) decomposition of organic matter and the industrial decomposition of organic waste?
Geology and Pedology	The analysis of two soil samples carried out in the laboratory reveal the following results regarding the solid-phase components and the Cation Exchange Capacity (CEC): Sample 01 60 % clay, 3% organic matter CEC = 76 $cmol_c \cdot kg^{-1}$ Sample 02 60 % clay, 2% organic matter and CEC = 30 $cmol_c \cdot kg^{-1}$ a) State which is main the type of clay in each soil sample b) Calculate the maximum amount of nickel retained by a soil layer of 27 cm and 1 hectare of each soil sample. The density is approximately of 1350 $kg \cdot m^{-3}$ for both of them. Give the results in kilograms. c) If an accident would happen, which of the soils would be able to retain more efficiently pollutants avoiding aquifers' contamination?

Figure 2. Three examples of activities

The macro problem was presented to the students at the end of the second week of the semester and a maximum of ten weeks were given for solving it. Each week each course takes up approximately four hours in the timetable. Working in faculty-supervised groups of not more than four members, as suggested by Oakley et al. (2004), students solved the partial problems. Simultaneously, students re-formulated the macro problem in terms that they could understand, devised an approach to a solution, identified what they knew and what they require to advance towards it, constructed new knowledge based on their previous knowledge and worked together to find a solution.

The supervision plan designed by the lecturers consisted of three personalized meetings distributed along the ten weeks. In such meetings, the students presented the lecturers their progress on the partial problems concerning each specific course and the macro

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problem and, they discussed about general issues too. These tutorials were not mandatory and they were performed on students' demand. Additionally, students could also ask explicit questions to a fourth-course student, who also took part in the PBL project as an advisor.

The PBL project was assessed through an oral examination at the end of the semester as well as on the basis of a written report. The oral examination committee was composed of the three lecturers involved in the PBL project. This oral presentation took the 30% of the PBL project score. The score of the oral presentation of each group was agreed by the committee. The remaining 70% of the PBL project score corresponded to the written report, divided into two parts: general approach (15%, agreed by the lecturers) and the solution to the partial problems (45%, each lecturer evaluated issues regarding his/her course). The PBL project counts for 15 to 20 percent of the total score in the courses involved in the project. Students' assessment in each course was completed with their participation in classroom activities, written reports, laboratory sessions, computer labs and a final written test (Gibbs and Simpson, 2005). Finally, students' perception about this innovative experience was compiled using two opinion polls: one before the PBL experience and another one, after it. They included 10-15 questions and the chance to add comments. The questions were related to their knowledge and interest in these three courses, skills and the PBL methodology.

Below, the effects of the PBL approach on the students' attitude towards the learning process together with the impact on the students' performance and success rates are presented.

3. Results and Discussion

Our PBL experience has been compared to that already used in other courses that are taught in the first and the second year of the degree in Environmental Engineering as well as to these courses when the traditional (lecture-based) methodology was used.

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3.1. Students' opinion on the PBL initiative

Our investigation reveals that during this experience the second year engineering students were considerable more active, cooperative and involved than with the traditional methodology: the class attendance was close to a 100% and they devoted more hours to study these three courses. Another point worth noting of this innovative experience was the good classroom atmosphere: students participated continuously and enthusiastically (frequently, one intervention per minute). This attitude was unusual with the traditional methodology. Hence, the PBL approach seems to be more effective in terms of capturing students' interest and sustaining motivation. These are some of the strengths reported in literature (Major and Palmer, 2001; MacAndrew et al., 2008).

From the survey conducted before applying the PBL methodology, it was deduced that the students' interest towards the utility of the three subjects involved in the project for their future professional practice, was *medium-high*. They showed the same degree level expectations in the opportunity of developing communication skills, decision making, autonomy to learn and ability to work in groups. Lastly, the possibility of obtaining a remarkable final score in the courses involved in this multidisciplinary project was considered *medium*.

Figure 3 shows part of the results obtained in the opinion poll conducted at the end of the semester, after the oral presentation to the committee. The 72% of students rated the experience as *quite satisfactory* and the 7% as *very satisfactory* (Figure 3, left). None of the students claimed they have learned *less*; moreover, the 72% stated that they have learned *more* and the 7% believe to have learned even *much more* with this approach than with the traditional methodology (Figure 3, middle). As illustrated in the left graph, the 75% will repeat again this experience. The most remarkable result was that all of the students felt that the assessment system was *adequate* (not shown); the reverse is actually the case of most PBL experiences.

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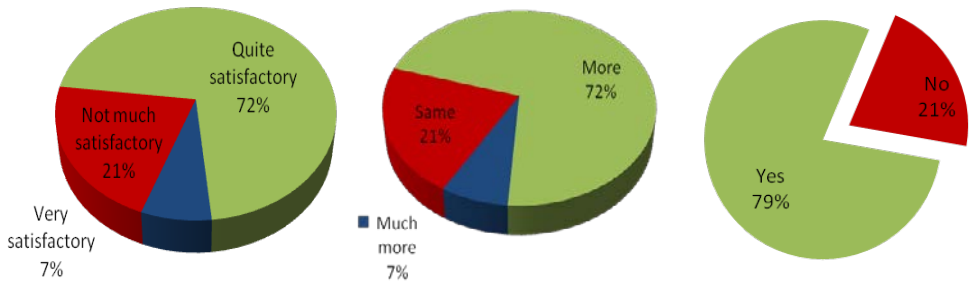

Figure 3. Summary of the results of opinion polls about the PBL experience

Regarding the contribution of PBL to developing skills for their future professional career, it should be stressed that the 79% of students considered it quite an adequate methodology for learning and the 64% said that it has been quite useful to understand better theoretical contents of the disciplines involved in the PBL experience as well as to investigate with more independently. Lastly, the 57% of the students think that the PBL approach helped them to take decisions on their own in the proposal of solutions to real-life problems and they also value the contributions of multiple fields to complex problems.

Table 1 presents the answers of improvement in certain abilities after the PBL experience. Students were asked to rate their level of expertness before and after the PBL methodology on a scale from 1 (very low) to 6 (very high). The coefficients of the column *improvement* have been calculated as the mean of the differences between results *before* and *after* the application of the innovative methodology. Results reveal that they think that there has been an improvement in all the evaluated abilities (the difference *after-before* is positive for all the evaluated competences) being higher in the following: diagnosis of environmental problems (+1.14), information search and analysis (+1.14), and preparation of technical reports (+1.07). In view of the obtained results, we can say that Problem-Based Learning promotes development of skills that are essential in the modern engineering profession as they are in demand by future employers. This perception agrees with the study by Akinoglu and Tandogan (2007) suggesting that PBL

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causes positive changes in social tendencies, such as making decisions with group members and team spirit.

Table 1. Students´ opinion on the usefulness of the PBL approach to help the development of several abilities

Skill	Improvement
Information search and analysis	1.14
Effective management of the time to study	0.07
Ability to learn by oneself	0.64
Diagnosis of environmental problems	1.14
Teamwork	0.64
Argumentation and critical analysis	0.43
Oral communication	0.36
Technical reports preparation	1.07

On the other hand, some of the students complain about the extensive work time; in their view, PBL was too time-consuming. The PBL did not "work" well with those students who did not attend to one of the three courses implied in the project. Similar drawbacks have been reported by other instructors and researchers (Kolari et al., 2008).

3.2 Impact of PBL on the academic results.

The improvement in success rates (approved/submitted), performance rates (approved/enrolled) and other ratios such as attendance, active participation and delivery of reports was remarkable for the 2013/2014 academic year.

Figure 3 shows the evolution in the percentage of students who took the test over the enrolled students. These data correspond to the last three academic years, which gather all the years in which the second course of the degree in Environmental Engineering has been active. The data show that this rate has increased considerably in the three courses involved in the PBL experience: 93.6% in Geology and Pedology (+5.6%), 86.4% in

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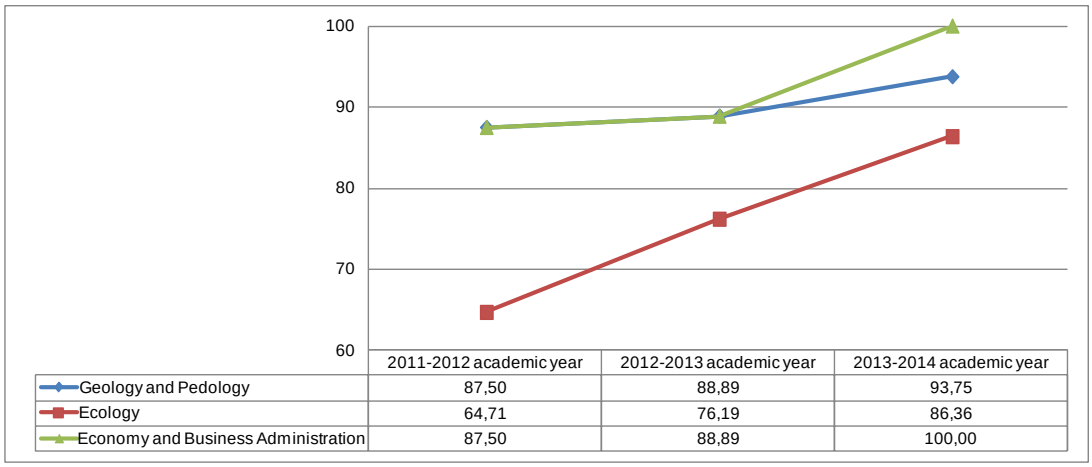
Ecology (+15.9%) and 100% in Economy and Business Administration (+11.8%). These data, together with the results obtained in the opinion poll, corroborate that the experience has motivated students in a significant way.



	2011-2012 academic year	2012-2013 academic year	2013-2014 academic year
Geology and Pedology	87,50	88,89	93,75
Ecology	64,71	76,19	86,36
Economy and Business Administration	87,50	88,89	100,00

Figure 4. Evolution of the percentage of students who took the final test over the enrolled students in Geology and Pedology, Ecology and Economy and Business Administration (It includes May and July calls)

The evolution of the average rates of submitted over enrolled for the three courses involved in PBL experiment versus the other six courses in the second year of the degree in Environmental Engineering is illustrated in Figure 4. It shows that while the rate of submitted over enrolled was greater for the rest of the courses in the academic year 2011-2012, in the academic year 2013-2014 (and also in 2012-2013) the rate of the students submitted over enrolled reach the 93.4% for the courses involved in the PBL experience; a rate that is considerably above the average for the rest of the courses. As a matter of fact, the rate of submitted over enrolled for the academic year 2013-2014 in the courses involved in PBL experience was greater than the average rate of the rest of courses in any year (first, second, third and fourth year), and even the average rate of all the courses belonging the second course of the degree.

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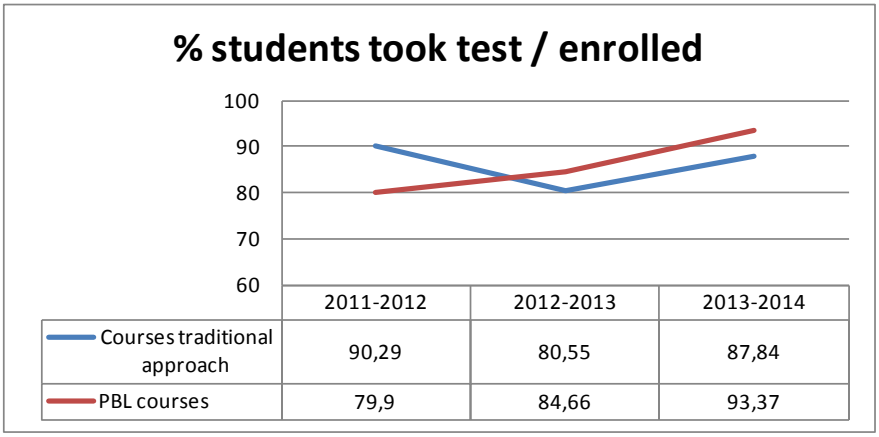

Figure 5. Evolution of the average rates of submitted over enrolled for the courses of the second year of the degree in Environmental Engineering. The courses applying the PBL approach (in red) are compared with the other ones, using lecture-based methods (in blue).

Figure 6 shows the evolution of the success rate, that is, the percentage of students who passed the test over students who took the test for the three courses involved in the PBL experience. Results reveal that in Ecology and Economy and Business Administration the success rates improved considerably in the academic year 2013-2014 compared to previous years: 81.8% (+10.8%) and 94.5% (+12.1%), respectively. These data are even more valuable if we consider that the rate of student who took the test over the enrolled students increased too. The course Geology and Pedology employed the PBL approach since the degree in started. This fact explains the absence of an improvement in the academic year 2013-2014, which in any case, were outstanding: an average of 85.9%.

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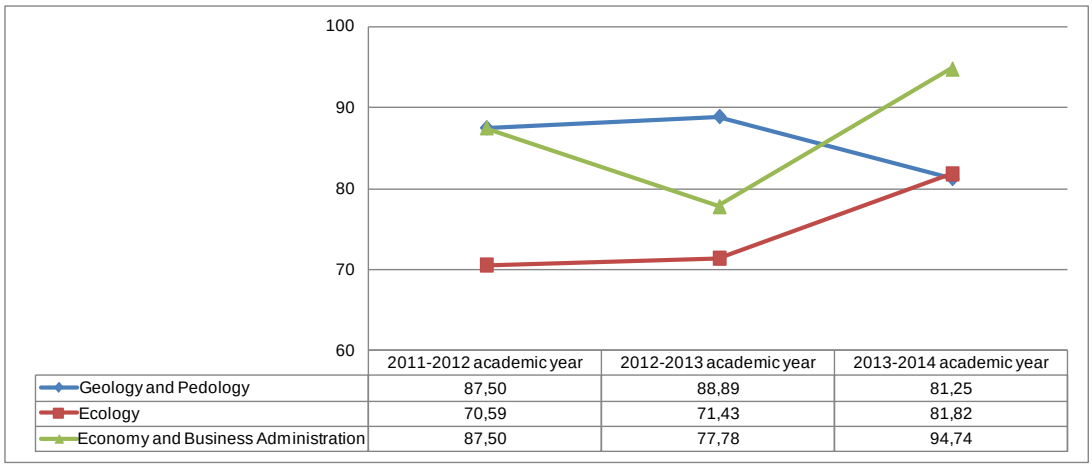

	2011-2012 academic year	2012-2013 academic year	2013-2014 academic year
Geology and Pedology	87,50	88,89	81,25
Ecology	70,59	71,43	81,82
Economy and Business Administration	87,50	77,78	94,74

Figure 6. Evolution in the percentage of students who passed the test over the ones who took the test in Geology and Pedology, Ecology and Economy and Business Administration in the last three academic years.

The evolution of the average success rates for the three courses involved in PBL versus the rest of the courses in the second course of the degree in Environmental Engineering is displayed in Figure 7. Results expose that success rates were greater in the courses involved in PBL project that for the rest of the courses. Nevertheless, a small decline of the average success rates for the courses involved in the project can be identified: from 95.3% to 93.8%. This is due to the considerable downturn in Geology and Pedology; it causes a slight downturn in the average rate besides the improvements in Economy and Business Administration and Ecology, which join the PBL methodology in academic year 2013-2014.

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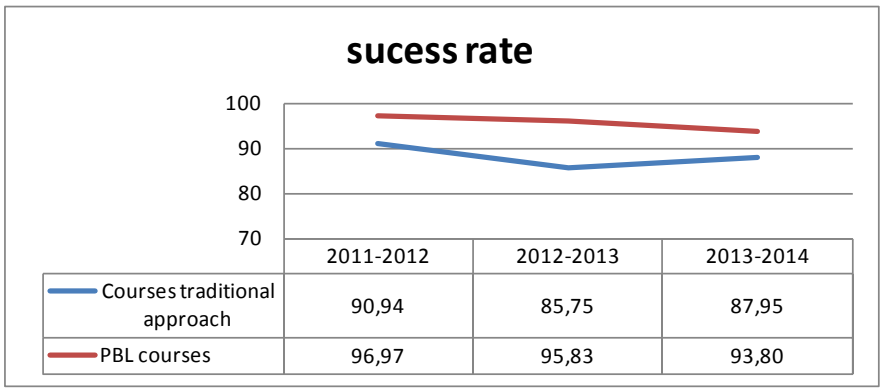

Figure 7. Same as Figure 5 for average success rates.

The evolution of the performance rate, that is, the percentage of students who passed the course, over the enrolled is displayed in Figure 8. In Economy and Business Administration and Ecology courses, the performance rates obtained in academic year 2013-2014 were higher than the ones obtained in previous years: 81.8% (+10.8%) and 94.7% (+12.1%). As in Figure 6, the absence of improvement in Geology and Pedology is explained by the fact that the PBL methodology was introduced in this course in academic year 2011-2012 and has continued since then.

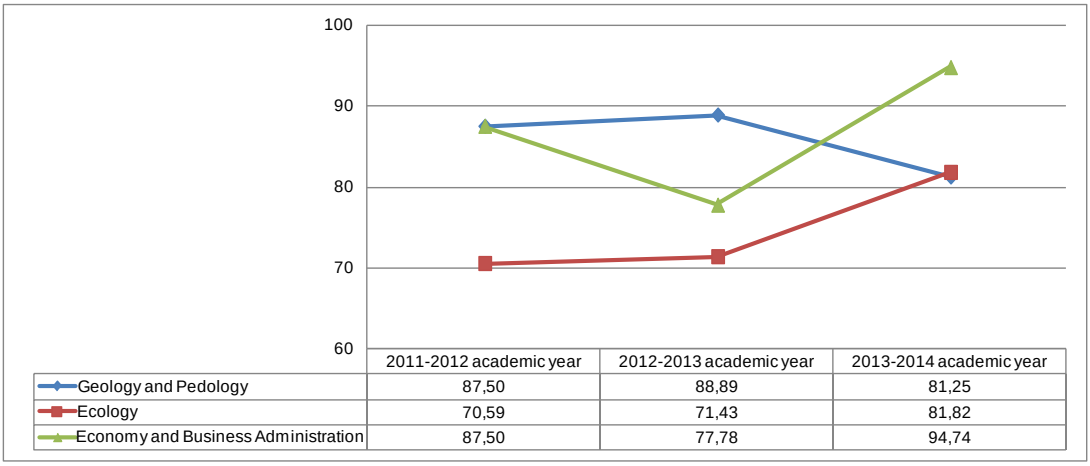

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Figure 8. Evolution of the performance rates in Geology and Pedology, Ecology and Economy and Business Administration in the last three academic years.

Figure 8 shows the evolution of the average performance rates for the three courses involved in PBL versus the rest of the courses in the second year of the degree. While in the academic year 2011-2012 the performance rate was greater for the rest of the courses (82.31%), in 2013-2014 the situation reversed: 87.5% *vs*. 77.7%. It is also remarkable that during the studied period the average efficiency rate for the three courses involved in PBL experience has increased nearly a 10 %.

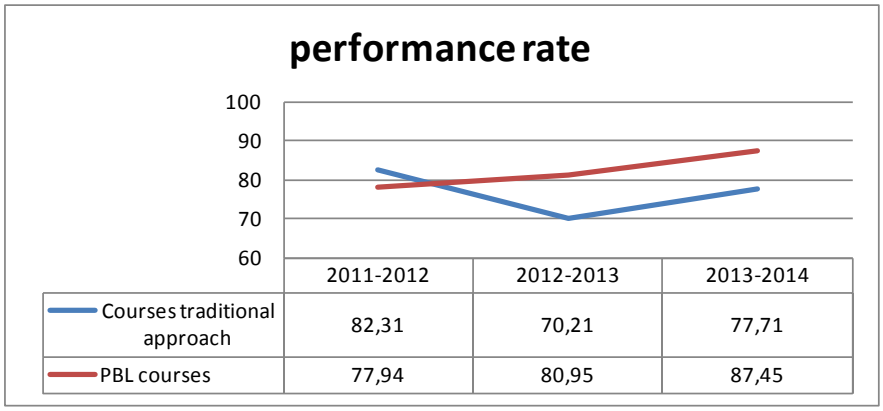

Figure 9. Same as Figure 5 for the average performance rates

The final grades of the courses involved in the PBL experience for the last three academic years are detailed in Table 2.The most remarkable result is the downturn in the percentage of students not taking the final test: 6.3% in Geology and Pedology (-5.6%), 13.6% in Ecology (-16.0%) and 0% in Economy and Business Administration (-11.8%). Moreover, there was an improvement in the final scores in Economy and Ecology compared to the previous academic year, looking more like the scores in year 2011-2012 (first promotion of the degree). It is also remarkable the increase in the rate of students who reach an *outstanding* score in Ecology in the academic year 2013/2014: 45.5%. We have also

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detected that the rate of students who reach an *outstanding* score increased in Economy and Business Administration (31.6%) and Geology and Pedology (37.5%) compared to year 2013/2014, getting closer to levels obtained in the academic year 2011/2013.

Table 2. Scores obtained in Geology and Pedology, Ecology and Economy and Business Administration in the last three academic years.

	Geology and Pedology			**Ecology**			**Economy and Business Administration**		
	2011-2012	**2012-2013**	**2013-2014**	**2011-2012**	**2012-2013**	**2013-2014**	**2011-2012**	**2012-2013**	**2013-2014**
Not submitted	12,50	11,11	6,25	35,29	23,81	13,64	12,50	11,11	0,00
Failed	0,00	0,00	12,50	5,88	4,76	0,00	12,50	11,11	5,26
Pass (5.0- 6.9)	37,50	66,67	43,75	41,18	71,43	40,91	31,25	72,22	63,16
Outstanding (7.0-8.4)	43,75	22,22	37,50	11,76	0,00	45,45	37,50	5,56	31,58
Excellent (8.5-10)	0,00	0,00	0,00	5,88	0,00	0,00	6,25	0,00	0,00
Honor (10.0 +)	6,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

The following tables show the preliminary results of the hypothesis contrasts designed to verify if the average scores in Economy and Ecology in 2013/2014 are greater than the ones in academic years 2011/2012 and 2011/2013. The same contrast is done for Geology, but we expect the average score to be similar throughout the three academic years for the aforementioned reasons. Table 3 shows the results of the basic statistics.

- Economy and Business Administration. The average grade in 2011/2012 was 6.35. In 2012/2013 the final scores decreased, while in 2013/2014, when the PBL method was introduced, it increased reaching a 5.43 average final score.
- Ecology. The average score in 2011/2012 was 5.46. In academic year 2012/2013 the average score decreased, and in 2013/2014, the year in which the PBL was introduced, it increased reaching an average score of 6.32.

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- Geology and Pedology. As we noted before, the PBL method was introduced in the academic year 2011/2012. Therefore, as expected, the average grade is very similar through the three academic years, between 6.1 and 6.6.

Table 3. Final scores and statistics in the three courses involved in the PBL experience for the last academic years

Course	Academic year	*N*	Average	Standard error average	Standard deviation
Economy and Business Administration	2011-12 2012-13 2013-14	17 19 26	6,3529 4,9158 5,4385	0,46795 0,26205 0,32430	1,92942 1,14225 1,65362
Ecology	2011-12 2012-13 2013-14	16 22 23	5,4625 5,0136 6,3174	0,50024 0,19141 0,24773	2,00096 0,89777 1,18807
Geology and Pedology	2011-12 2012-13 2013-14	17 18 16	6,5471 6,0056 6,0875	0,39380 0,29885 0,37248	1,62370 1,26792 1,48991

Table 4 shows the results of comparing the scores of course 2012/2013 with the ones obtained in course 2013/2014 using Levene and *t* test. In our case the samples are independent, thus, we used the *t* test for independent samples.

- Economy and Business Administration. We deduce that the variance are different since p-value= 0.028 < 0.05 so we used the information corresponding that assumption. Since p-value= 0.217 > 0.05 we cannot reject the hypothesis of average equality.
- Ecology. We deduce that the variance are different since p-value= 0.012 < 0.05 so we used the information corresponding that assumption. Since p-value= 0,140 > 0.05 we cannot reject the hypothesis of equality (confidence level of 95%).
- Geology and Pedology. In this case, there are no reasons to believe that the variances are different since p-value=0.363 > 0.05. Assuming equality in

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variances we find that we can't reject the hypothesis of average equality (confidence level of 95%) since p-value = 0.864 > 0.05.

Table 4. Results of statistical tests for the three courses involved in the PBL experience for the last academic years

		Levene's test Analysis of variances		*t* test Analysis of the averages		
		F	Significance	t	Degrees of freedom	Significance (bilateral)
Economy and Business Administration	Equal variances Not equal variances	5,194	0,028	1,185 1,254	43 42,904	0,243 0,217
Economy	Equal variances Not equal variances	7,037	0,012	1,673 1,531	37 22,343	0,103 0,140
Geology and Pedology	Equal variances Not equal variances	0,853	0,363	0,173 0,172	32 29,677	0,864 0,865

4. Conclusions

We have presented a case study of the PBL approach in the second year of the degree in Environmental Engineering. The experiment was applied in the academic year 2013-2014. Introducing the PBL to three courses was motivated by the desire to engender a learning context favoring enthusiasm, the establishment of links between concepts and their applications together with the proposition of integral a cross-disciplinary solutions to environmental problems.

Our findings clearly demonstrate that the students' attitude improved significantly from previous academic years or respect to other courses using traditional (lecture-based) methods. The students' participation and the interaction (both student-student and instructor-student) were higher compared to other non-PBL courses. Our investigation also reveals that this positive attitude and implication led to better academic results. Moreover, the PBL helped undergraduates to develop of a number of skills that are

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critical for their career, such as the ability to function on multidisciplinary teams and to understand the impact of engineering solutions in a global, economic, environmental and societal context. Finally, it should be emphasized that we have encountered some drawbacks and difficulties (such as an inconsistency between the new educational format and the form or examination or the harmful effects of a harder work in these courses on the results obtained in the other ones) that offer opportunity for further research and adjustments.

5. References

Accreditation Board for Engineering and Technology (ABET). Engineering Accreditation Commission (2013). Criteria for Accrediting Engineering Programs. http://www.abet.org/DisplayTemplates/DocsHandbook.aspx

Akinoglu O. and Tandogan R.O. (2007). The Effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. *Eurasian Journal of Mathematics, Science & Technology Education* 3 (1), 71–81.

American Academy of Environmental Engineers (AAEE) Environmental Engineering Body of Knowledge Working Group (2008). Environmental Engineering body of knowledge: summary report. Environmental Engineer Environmental Engineer: Applied Research & Practice, 6. http://www.aaees.org/

Borrego M. and Newswander L.K. (2007). Characteristics of successful cross-disciplinary engineering education collaborations. *Journal of Engineering Education*, 97 (2), 123-134. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00962.x

Crawley E.F., Malmqvist J., Ostlunf S. and Brodeur D. (2007). *Rethinking Engineering Education*. The CDIO Approach. 286 pp. ISBN: 978-0-387-38287-6.

http://dx.doi.org/10.4995/muse.2015.3697
EISSN: 2341-2593

De Graaf E. and Christensen C.H. (2004). Editorial: Theme Issue on Active Learning in Engineering Education. *European Journal of Engineering Education*, 29 (4), 461-463. http://dx.doi.org/10.1080/03043790410001716310

De Graaf E. and Kolmos A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19 (5), 657-662.

Felder R.M. and Brent R. (1994). Cooperative learning in Technical Courses. A monograph presenting suggestions for effective implementation of cooperative learning in engineering and science courses. ERIC Document Reproduction Service, ED 377038. http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Education_Papers-Chronological.html

Gibbs G. and Simpson C. (2005). Conditions under which assessment supports student's learning. *Learning and Teaching in Higher Education*, 1, 3-31.

Hmelo-Silver C.E. (2004). Problem-Based Learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266. http://dx.doi.org/10.1023/B:EDPR.0000034022.16470.f3

Kolari S., Savander-Ranne C. and Viskeri, E.J. (2008). Learning needs time and effort: a time-use study of engineering students. *European Journal of Engineering Education*, 33(5-6), 483-498. http://dx.doi.org/10.1080/03043790802564046

Kolmos A. (1996). Reflections on Project Work and Problem-based Learning. *European Journal of Engineering Education*, 21(2), 141-148. http://dx.doi.org/10.1080/03043799608923397

MacAndrew S., Walsh L., Oduyemi K. and Lantz C. (2008). Problem based learning in practice: listening to the lecturers. An investigation of academics' perceptions and practice concerning problem based learning. Scottish Higher Education Enhancement Research (2) Final report.

http://dx.doi.org/10.4995/muse.2015.3697
EISSN: 2341-2593

Major C.H. and Palmer B. (2001). Assessing the effectiveness of Problem-Based Learning in Higher Education: Lessons from the Literature. *Academic Exchange Quarterly*, 5(1), 4-9.

Markes I. (2006). A review of literature on employability skill needs in engineering. *European Journal on Engineering Education*, 31(6), 637-650. http://dx.doi.org/10.1080/03043790600911704

Mills J.E. and Treagust D.F. (2003). Engineering education is Problem-based or Project-based Learning the answer? *Australian Journal of Engineering education*, 1-16.

Ministerio de Educación, Cultura y Deporte (2011). Resolución de 20 de diciembre de 2010, de la Universidad del País Vasco, por la que se publica el plan de estudios de graduado en Ingeniería Ambiental. Boletín Oficial del Estado, 26, 31 de enero de 2011, Sec. III, p. 10782.

Oakley B., Felder R.M., Brent R. and Elhajj I. (2004). Turning students into effective teams. *Journal of Student Centered Learning*, 2(1), 9-34.

Richter D.M. and Paretti M.C. (2009). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education*, 34(1), 29-45. http://dx.doi.org/10.1080/03043790802710185

Walker A. and Leary H. (2009). A Problem Based Learning Meta Analysis: Differences Across Problem Types, Implementation Types, Disciplines, and Assessment Levels. *Interdisciplinary Journal of Problem-Based Learning*, 3(1), 6-28. http://dx.doi.org/10.7771/1541-5015.1061

http://dx.doi.org/10.4995/muse.2015.3697
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