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PROFESSIONAL SKILLS DEVELOPMENT IN ENGINEERING EDUCATION AT THE UNIVERSITY OF THE BASQUE COUNTRY: PROBLEM OR PROJECT BASED LEARNING?

EL DESARROLLO DE HABILIDADES PROFESIONALES EN LOS ESTUDIOS DE INGENIERÍA EN LA UNIVERSIDAD DEL PAÍS VASCO: ¿APRENDIZAJE BASADO EN PROBLEMAS O PROYECTOS?

Zaloa Aginako Arri[1] – Industrial Engineer
Mikel Garmendia Mujika[2] – PhD in Engineering
Mª José Bezanilla Albisua[3] – PhD in Education
Eneko Solaberrieta Mendez[4]– PhD in Engineering

[1] Engineering school of Bilbao, University of the Basque Country UPV/EHU, Electrical Engineering Department, Rafael Moreno nº 3, 48013 Bilbao, 946014388, zaloa.aginako@ehu.eus

[2] Faculty of Engineering of Gipuzkoa University of the Basque Country UPV/EHU, Graphic Expression and Engineering Projects Department, Pza. Europa 1, 20018 Donostia (Gipuzkoa), mikel.garmendia@ehu.eus.

[3] Faculty of Psychology and Education University of Deusto, Department of Innovation and Educational Organisation, Avenida de las Universidades 24, 48007 Bilbao, (Bizkaia), marijose.bezanilla@deusto.es

[4] Faculty of Engineering of Gipuzkoa University of the Basque Country UPV/EHU, Graphic Expression and Engineering Projects Department, Pza. Europa 1, 20018 Donostia (Gipuzkoa), *eneko.solaberrieta@ehu.eus*

ABSTRACT:
In engineering education, when choosing methodologies to promote the development of professional skills that satisfy both, the requirements of the evaluation agencies and employers, two options, among others, are being considered: Problem-based learning (PBL) and Project-based learning (PjBL).However, there is a certain discrepancy in published research regarding to the suitability of applying one or other methodology, and about the way they should be integrated into the engineering academic programs. Moreover, no meta-analysis using a significant number of subjects has been found in the literature that quantitatively compares the influence of both methodologies to the development of professional skills. This study makes a first approach using the students' assessment of the methodologies, with a questionnaire, as common comparison test. A set of statistical tests of comparison of means values were conducted between two groups of students (PjBL and PBL students). The results show that project-based learning seems to have more influence to develop professional skills in engineering studies at the University of the Basque Country.

Keywords: Problem-based learning, Project-based learning, professional skills, engineering education

RESUMEN:
En los estudios de ingeniería, a la hora de elegir metodologías que promuevan el desarrollo de competencias profesionales que satisfagan tanto los requerimientos de las agencias de evaluación como de los empleadores, entre otras, se están barajando principalmente dos opciones: el Aprendizaje Basado en Problemas (ABP) y el Aprendizaje Basado en Proyectos (ABPY). Sin embargo, existe cierta discrepancia en las investigaciones publicadas en cuanto a la idoneidad de aplicar una u otra metodología, y la forma en la que se deben integrar en el programa académico. En la actualidad no se dispone de un metaanálisis realizado con un amplio número de asignaturas que comparen la diferencia entre las dos metodologías en el desarrollo de competencias profesionales de forma cuantitativa. Este estudio realiza una primera aproximación, utilizando la valoración de los estudiantes como prueba común de comparación, empleando para ello un cuestionario de elaboración propia. Se han llevado a cabo una serie de pruebas estadísticas de comparación de medias entre los dos grupos de estudiantes de la muestra (uno ABP y otro ABPY). Los resultados muestran que el aprendizaje basado en proyectos parece tener más influencia en el desarrollo de competencias profesionales que el ABP en los estudios de ingeniería de la Universidad del País Vasco (UPV/EHU).

Palabras clave: Aprendizaje basado en problemas, aprendizaje basado en proyectos, habilidades profesionales, educación en ingeniería

1.- INTRODUCTION

The new professional profile demanded for engineers of the 21st century is a fact reflected in the requirements of engineering degrees' accreditation agencies all over the world –ABET (USA), AEAC (Australia), ENAEE (Europe), etc. All agents, including future employers, recommend educational institutions to train engineers with problem-solving skills (to solve complex and multidisciplinary problems), being able to work in groups (including multicultural environments), and to learn throughout of life, with strong communication skills in addition to traditional technical skills. (Association of American Colleges & Universities, 2015, cited in [1]).
Felder and Brent [1], in order to help lecturers to develop the previously mentioned professional skills with their students, group them into main five: communication (oral and written), creative thinking (seeking innovative solutions to problems when existing current approaches are inadequate), critical thinking (performing and supporting evidence-based

assessments and decisions), self-directed learning (taking the initiative to identify own learning needs, find the needed resources to undertake them and learn) and teamwork.

In spite of the wide range of methodologies that exists to develop professional skills in engineering education, Project-Based Learning (PjBL) and Problem-Based Learning (PBL) approaches have a global presence, in part, thanks to the UNESCO Chair in Problem-Based Learning[1] at Aalborg University, which has actively contributed to their divulgation. This presence, however, is not exempt from some discussion among professionals in the area, regarding to the preference of one or the other approach (PBL or PjBL) for the engineers' education [5].

Although PBL and PjBL have been used since the 80's of the last century, they have been taken up again strongly in recent decades precisely to link learning to real contexts, which favours the development of professional skills, such as critical thinking [2], adaptation to the work environment [3], technical reasoning and self-directed learning [4].

Over Project-Based Learning, Harmer [6], in a literature review, indicates that the main reason given for introducing the PjBL in engineering education is that the method provides the type of skills, behaviours and learning necessary to face the challenges in the contemporary context of increasing complexity, where the problems and projects transcend the defined disciplines of the classic sectors of engineering. Felder and Brent [1], additionally, consider that PjBL creates a lot of motivation and the appropriate context to acquire and develop professional skills, and they add that students following a PjBL approach obtain better or equal results in the knowledge tests than students who follow a traditional methodology. And, in the same vein, Mills and Treagust [5] affirm that PjBL is the methodology that responds to the requirements of accreditation agencies, as well as to the needs of the industry, and they consider as very appropriate its inclusion in engineering programs.

With regard to problem-based learning Jonassen [7] considers that, within traditional teaching, students learn to solve problems hardly transferable to the work environment, and he adds that PBL is the methodology that engineering educators must adopt if they want their graduates to be effective engineers. It should also be noted that there is ample evidence about its effectiveness as a method to promote extensive ranges of reasoning [8], retention of long-term learning [1] and problem-solving skills [7] when applying it in a subject.

But, what these methodologies consist of? Both have certain common aspects: they involve the student actively in the learning process, working autonomously and in teams with the teacher's support. However, the focus and the development in the classroom of the two methodologies is different, as it is reflected in the definition that Prince and Felder [8] give of both approaches, emphasizing their differences: "Problem-based learning (PBL) begins when students are confronted with an open-solution, unstructured and authentic (real context) problem, and work in teams to identify their learning needs and develop a viable solution, teachers act as facilitators rather than a source of information". It is convenient to point out that the PBL should not be confused with the simple use of problems and exercises in teaching. In PBL, students must analyse the given scenario, identify their learning needs and the possible steps to solve the problem, and search and learn the necessary contents by themselves, not having the teacher previously exposed those contents nor the process to follow to solve the problem. In this sense, it is a methodology highly focused on self-directed (or autonomous) learning of the students group.

"Project-based learning begins with the assignment of carrying out one or more tasks that lead to the production of a final product – a design, a model, or a computer simulation. The culmination of the project is usually a written and/or an oral report that summarizes the procedures used in the production of the product and in which the results are reported" [8].

In general, and according to the consulted researches, both methodologies are successfully implemented in engineering programs, at degrees and masters levels. However, the current debate among researchers in the area is focused on the suitability of using one or other method and the way they should be introduced in engineering curriculums. Some authors, such as Perrenet et al. [9] and Mills et al. [5] even consider that the PBL can't respond by itself to the needs of engineering programs, due to the structure in which learning is developed in this area. It seems that a mixed proposal using the PBL in initial courses to give a real context to the problems, followed by PjBL in the higher courses to address complex and interdisciplinary problems can be a very beneficial solution in engineering programs [5 and 9].

In some models, such as the model of the Aalborg University (Denmark) both approaches are combined throughout the training program. Other authors, such as Felder and Brent [1] propose the PBL as an adequate methodology to develop problem-solving skills, and the PjBL to develop professional skills.

But beyond recommendations from researchers in the area, and experiences in specific subjects, in which these methods are compared with traditional teaching, no meta-analysis has been developed addressing conclusively the suitability of PBL and PjBL for the development of certain professional skills in the field of engineering.

On the other hand, experiences in specific subjects do not provide comparable values among them, since they have been carried out with different research designs and contexts. Consequently, this study, based on assessments given by students, aims to evaluate the effectiveness of one or the other method (PBL and PjBL) in the development of certain professional skills in a similar context, that is, engineering education at the University of the Basque Country (UPV / EHU).

[1] www.ucpbl.net

2.- MATERIALS AND METHODS

To evaluate the effectiveness of two methods, students were asked to assess to what extent did PBL or PjBL methodology help them to acquire or develop a series of professional skills and aspects of learning (first column, table I), the survey was conducted using a self-made questionnaire designed ad hoc. for this research. In the questionnaire a Likert scale of four levels was used, being its coding: 1: very little, 2: little, 3: quite a lot and 4: a lot. The items were chosen based on the professional skills and learning aspects the researchers point out that are developed with the PBL and PjBL approaches. The references to these researchers and the competences they claim, are reflected in the introduction of this document.

The questionnaire was conducted among subjects of engineering schools of the UPV / EHU, in those subjects the PBL or PjBL methodology was implemented by teachers who had participated previously in a training program called ERAGIN [10]. The lecturers were trained in one of the two methods, in an extensive formative program, in which they received an initiation workshop, and later, with the advice of a tutor, they designed an active teaching proposal that they implemented in the classroom. Finally, they evaluated the result obtained in the experience. As a part of the process of the experience evaluation by both teachers and students, the students' evaluation was collected using the questionnaire. At last, responses of 1224 students of 44 subjects were available for analysing, in 25 of those subjects PjBL methodology was implemented and in 19 PBL. They are subjects of the four academic years of the engineering degrees (41) and of the masters on industrial technologies and telecommunications (3). And they include all types of subjects typified in the curricula: basic branch (16), compulsory (26) and elective (2). The subjects belong to engineering degrees and masters taught at the UPV / EHU, such as industrial engineering, telecommunications, organization, civil engineering, environmental engineering, mines, etc. Therefore, the sample is constituted by students of the same university (UPV-EHU) of similar demographic characteristics who attend engineering degrees of similar structure and projection. From 1224 students of the sample who took part in a subject with these active methodologies, 553 did it with the PBL approach and 661 with PjBL, all of them in similar conditions in relation to the duration and context of the implementation in the classroom.

The results of each item of the questionnaire, have been analysed by contrast of means between the two comparison groups (PjBL subjects and PBL subjects), so that it has been possible to quantify the difference that exists in the assessment of each group of students about the professional skills developed and certain aspects of learning after having completed a subject with one of the two methodologies.

For the comparison of means, two statistical tests were used, the *t* student test for independent samples and the Mann Whitney *U* test; the last one, in the cases where conditions to apply the first one, were not met.

3.- RESULTS

The results of the statistical tests which compare the means values of both groups (PBL and PjBL), for each item, are shown in table number I. In the first column the statements of the questions (or items) are collected. The items, at the same time, are grouped into two dimensions: Skills and aspects of learning. The following two columns show the means values of the two compared groups (PBL and PjBL) for each item. And in the fourth column, the differences of means values are calculated given in percentage over the mean value of the PBL group. Note that the items have been ordered according to the values of this fourth column from highest to lowest for each dimension. Finally, the *p*-value and the effect-size are calculated in the last two columns, using the effect-size it is possible to assess whether the difference between the two samples is large or small.

Active method (PBL or PjBL) helped you to: (1: very little, 2: little, 3: quite a lot, 4: a lot)		**PjBL Mean**	**PBL Mean**	**DIFFERENCE** (%)	***p***	**EFFECT SIZE Cohen's *d***
SKILLS	Analyse situations belonging to professional practice	3,25	2,74	18,82	0,000	1,27
	Inquire on your own about the proposed work	3,33	2,93	13,72	0,000	1,42
	Solve problems or provide solutions to real situations	3,17	2,84	11,80	0,006	0,97
	Make decisions about a real situation	3,18	2,84	11,72	0,020	0,77
	Develop your learning autonomy	3,13	2,85	9,94	0,003	1,00
	Improve your team-work skills	3,31	3,03	9,46	0,001	1,07
	Develop your communication skills (oral or written)	2,97	2,73	8,82	0,015	0,79

LEARNING-ASPECTS	Develop skills needed in professional practice	3,10	2,64	17,27	0,000	1,27
	Increase interest and motivation towards the subject	3,08	2,65	16,19	0,016	0,78
	Take a participatory attitude towards your own learning	3,27	2,88	13,72	0,000	1,39
	Make connections between contents of the subject and obtain an integrated vision	3,12	2,81	10,90	0,010	0,79
	Establish relations between theory and practice	3,28	3,02	8,73	0,017	0,77
	Understand theoretical contents	2,89	2,80	3,12	0,522	0,20

(*) For $p < 0,05$ mean-values differences are statistically significative.

Table I. PBL and PjBL methodologies assessment. Survey's and statistical tests' results.

Broadly speaking, students assess that the methodology helped them to develop a series of professional skills and that favoured certain aspects of learning between little and quite a lot among PBL students group, and between quite a lot and a lot in the PjBL group, being in most of the items the means values around 3 (quite a lot). It is also noted that for all the items the mean value is higher in the PjBL group, with differences between a minimum of 3,11% and a maximum of 18,8%. These differences between the two groups are statistically significative ($p < 0,05$) for all the items except one, the item "to understand theoretical contents". The effect-size for the rest of the items is large according to Hattie criteria, who for educational innovations fixes as large effect, that in which the Cohen *d* is bigger than 0,6.

4.- DISCUSSION

The results of this study show that engineering students of the UPV / EHU who have followed the PjBL methodology assess the effectiveness of the method to a greater extent, than those who have followed a PBL approach, both to acquire professional skills and to favor certain aspects of learning. The item "analyse situations of professional practice", as well as the item "develop necessary competences in professional practice", both linked to ***work practice***, are the ones with the greatest differences among methodologies, 18,8% and 17,3% respectively. Students consider that they contextualize better the learning and develop more professional skills with the use of PjBL. This result of our study confirms empirically the claims made by other authors [1, 6, and 9]. On the other hand, it is noted that PjBL is more appropriate than PBL to promote students' ***autonomous learning*** (or self-directed) learning capacity in line with Perrenet's assertion [9].

Students consider that with the PjBL they investigate more on their own to find solutions to the problem (13,7% more than in the PBL), develop more autonomy to learn (9,9% more), and take a more participative attitude in relation to their learning (13,7% more). It should be remembered that the skills mentioned are directly related to the ability to learn throughout life that demands the engineer's new profile for the 21st century [1].

"Inquire on your own about the proposed work" is the item that receives the highest rating among the skills developed with the PjBL (3,33), also is that whose difference has the largest effect-size ($d = 1,42$).

Being one of the skills most demanded by employers [5], "Improving your team-work skills" is the second most valued skill when using PjBL (3,31) and despite being the most valued in PBL (3,03) a significant difference and a large effect-size is obtained on the side of the PjBL. In most research articles, PBL is presented as the methodology that promotes ***problem-solving ability*** [3, 7 and 2]. It is true that this skill is developed in the PBL, but one of the relevant contributions of our analysis is, that according to the results obtained in this case study in the item "solve problems or provide solutions to real situations", this skill is developed more using the PjBL. The difference between the mean values of PjBL and PBL students is 11,8% with a large effect-size, in favour of PjBL.

In addition to the professional skills, from the results of the surveys, other consequences about other learning aspects that promote these methodologies can be extract. Thus, for students, the PjBL "increase interest and motivation towards the subject" to a greater extent than PBL does (16,2% more), which is consistent with Felder's statements [1] who ensures that the PjBL methodology creates a ***motivating*** environment for students. Both methodologies are equally effective in promoting ***practical or applied learning***, since the item "establish relations between theory and practice" is in both methodologies one of the three most valued, with one of the smallest differences. Regarding the item "understand theoretical contents" it does not present a significant difference between the two methodologies, and although it is valued a little better in the PjBL (2,89), it is which receives the lowest value of all the items among the PjBL students. In this sense, the Perrenet thesis is supported [9] who maintains that the PjBL would be more oriented to the applications of contents, while the PBL would be focused rather on the acquisition of knowledge. Depending on the particular objectives of a subject or the content to be taught, it would be recommended to assess in each case the suitability of using one or another methodology, or even choose the inclusion of both throughout the program, thus leading to a hybrid curriculum. The way to integrate them into the curriculum of engineering courses and analyse how best results are obtained, currently constitute possible lines of research to be developed in the future. In addition, it would be of great interest to delve into this topic, with studies that allow to know the effectiveness of the methodologies to develop professional skills using a common test established by consensus to evaluate the professional skills in engineering and using an external evaluation-board, composed of professionals and academic staff.

5.- CONCLUSIONS

Finally, as a general conclusion of this case study in the UPV / EHU, students' assessments seem to indicate that it could be more effective to use preferably the Project-Based Learning methodology instead of Problem-Based Learning, in order to achieve greater development of professional skills. Especially those related to the analysis of professional situations, inquiry, problem-solving, decision-making, autonomy to learn, team-work, and communication. One of the relevant contributions of our analysis is that, according to the students' assessment, the problem-solving ability would also be developed more using Project-Based Learning than, by the use of Problem-Based Learning. These results, although they are not directly generalizable to other contexts different to those described in this paper, may be interesting to be analysed in other higher education institutions that consider the use of active methodologies such as PBL and PjBL for their engineering students. According to the results of our study, Project Based Learning should be considered as a preferential methodological option for the development of professional competences in engineering education.

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