PROBLEM-BASED LEARNING (PBL) AND INTERDISCIPLINARITY IN SOFTWARE ENGINEERING TEACHING-LEARNING

PROBLEM-BASED LEARNING (PBL) E INTERDISCIPLINARIDADE NO ENSINO-APRENDIZAGEM DE ENGENHARIA DE SOFTWARE

PROBLEM-BASED LEARNING (PBL) Y INTERDISCIPLINARÍA EN LA ENSEÑANSA Y APRENDIZAGE DE INGENIERÍA DE SOFTWARE

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ABSTRACT: Higher education is determinant in the construction of a society in its different dimensions. The ability to solve problems requires interdisciplinary skills. The goal of this action research was to evaluate the effectiveness of problem-based learning (PBL) for interdisciplinary teaching in software engineering (TSW). Tutorials were conducted with students of an Information Systems course. A questionnaire was applied to those who experienced the proposed method, also applied to former students who had graduated two years ago and to the students of the initial phases. When comparing the results of each group, it was evidenced that the PBL, as applied, contributed significantly to the construction of a more comprehensive view of the student about TSW and the impact of its products on society.

KEYWORDS: Interdisciplinarity. Integral education. Software Engineering.

RESUMO*: A educação superior é determinante na construção de uma sociedade em suas diferentes dimensões. A capacidade de resolver problemas requer competências interdisciplinares. O objetivo desta pesquisa-ação foi avaliar a efetividade da problem-based learning (PBL) para o ensino interdisciplinar em engenharia de software (ESW). Foram conduzidas tutorias com alunos de um curso de Sistemas de Informação. Um questionário foi aplicado àqueles que passaram pelo método proposto, em egressos de dois anos anteriores e em alunos das fases iniciais. Ao comparar os resultados de cada grupo, evidenciou-se que a PBL, tal qual aplicada, contribuiu de forma significativa na construção de uma visão mais abrangente no estudante acerca da ESW e o impacto de seus produtos na sociedade.*

PALAVRAS-CHAVE*: Interdisciplinaridade. Educação integral. Engenharia de software.*

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***RESUMEN**: La educación superior es determinante en la construcción de una sociedad en sus diferentes dimensiones. La capacidad de resolver problemas requiere competencias interdisciplinarias. El objetivo de esta investigación-acción fue evaluar la efectividad del problem-based learning (PBL) para la enseñanza interdisciplinaria en ingeniería de software (ESW). Fueron realizadas tutorías con alumnos de un curso de Sistemas de Información. Un cuestionario fue aplicado a aquellos que pasaron por el método propuesto, a los egresados de dos años anteriores y a los alumnos de las fases iniciales. Al comparar los resultados de cada grupo, se evidenció que la PBL, tal cual aplicada, contribuyó de forma significativa en la construcción de una visión más amplia en el estudiante acerca de la ESW y el impacto de sus productos en la sociedad.*

***PALABRAS CLAVE**: Interdisciplinariedad. Educación integral. Ingeniería de software.*

Introduction

The Constitution of the Federative Republic of Brazil, in its article 205, determines that education must aim at “the full development of the person, his preparation for the exercise of citizenship and his qualification for work”[4] (BRASIL, 1988, p. 123). As regards, more specifically, higher education, LDB (1996) in its article 43, establishes among the purposes of this level of education: the encouragement of “cultural creation and the development of the scientific spirit and reflective thinking”[5]; the formation of graduates “able to enter professional sectors and participate in the development of Brazilian society”[6]; encouraging “knowledge of the problems of the present world, in particular national and regional ones” and; “Provide specialized services to the community and establish a reciprocal relation with it”[7] (BRASIL, 1996, p. 32-33).

These conceptions assume that education must be integral, making possible, according to Rios (2009), not only formation in the technical dimension, but also in the dimensions, aesthetics, politics and ethics. In this context, with regard to undergraduate courses in the field of computing, its National Curricular Guidelines include among its recommendations: the “implementation of interdisciplinarity”, the “integration between theory and practice” and “research as an instrument for teaching activities”[8] (BRASIL, 2016, p. 2). This is because a super-specialized formation, which disregards the multiple disciplinary interactions present in

[4] “ao pleno desenvolvimento da pessoa, seu preparo para o exercício da cidadania e sua qualificação para o trabalho”
[5] “criação cultural e ao desenvolvimento do espírito científico e do pensamento reflexivo”
[6] “aptos para a inserção em setores profissionais e para a participação no desenvolvimento da sociedade brasileira”
[7] “conhecimento dos problemas do mundo presente, em particular os nacionais e regionais” e; “prestar serviços especializados à comunidade e estabelecer com esta uma relação de reciprocidade”
[8] “implementação da interdisciplinaridade”, a “integração entre teoria e prática” e a “investigação como instrumento para as atividades de ensino”

real problems, fails to meet, not only the constitutional principle of education, but also the contemporary needs about what is expected of a professional.

For this reason, it is believed that an interdisciplinary formative process can be an effective way to conduct comprehensive education. Interdisciplinarity, in turn, although it is not yet possible, as stated by Fazenda (2012), to point to a universal and consensual definition capable of clearly conceptualizing it, in this work we adopt the definition that describes it as the result of "organization of science to an end "(JANTSCH, 1970, p. 15), leading to the conception of an axiomatic common to a set of disciplines, with the objective of meeting a given purpose. This definition is also in line with what Carneiro Leão (1991) says, which states that the **finality** is the greater purpose of scientific advances, and that it is from interdisciplinary interaction that technologies emerge to meet these specific **goals**.

In the educational context, Severo (2018) states that interdisciplinary work can contribute significantly to overcoming the boundaries imposed by the current curriculum in most educational institutions, where the content is segmented and isolated in curricular units. In this sense, according to Córdova and Baade (2017), one of the teaching-learning techniques capable of promoting interdisciplinary interactions with well-directed **goals**, therefore meeting the requirements of an interdisciplinary teaching, is Problem-Based Learning (PBL). This is because, according to Schmidt (1983), among the principles of PBL are: the activation of previous knowledge, the specificity of coding and the elaboration of knowledge by the student. These principles assist in the development of problem-solving skills based on the interaction with real situations, through interdisciplinary knowledge and placing the student as the protagonist of the process.

However, despite the recommendations in the national curricular guidelines and the possible possibilities with the PBL, few effective actions are observed in the scope of undergraduate courses in the area of computing to promote education that surpasses primarily technical or market interests.

The objective of this work was to evaluate whether the possibilities identified for PBL, as a teaching-learning technique, for conducting an interdisciplinary formative process are realized and are capable of promoting an education closer to integral. For this, using the technique of the seven steps of Schmidt (1983), an intervention was carried out with academics from a university in the Midwest of Santa Catarina, Brazil. This intervention consisted of conducting classes using the PBL. Subsequently, the effectiveness of the applied method was assessed, through the application of a questionnaire in three different groups.

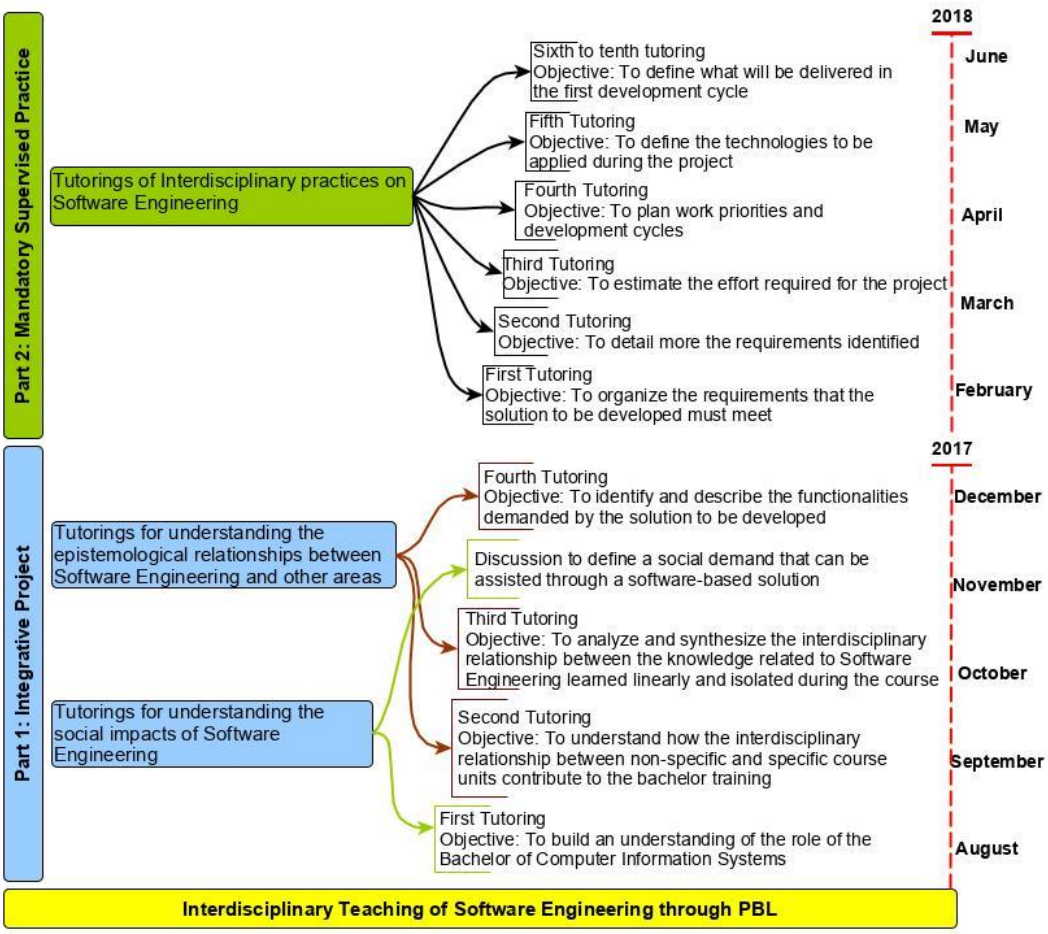
The results make an important contribution for educators in the computing area, more specifically, in software engineering. We believe that the search for improvements in the formative process must be constant in the profession of educator.

Methods

This work is the result of a year of action research carried out at a university in the Midwest of Santa Catarina, Brazil. This is an intervention in the integrative project and mandatory supervised internship of the same class of the Information Systems undergraduate course, in the second semester of 2017 and the first semester of 2018, respectively. Participated in the action research, students regularly enrolled in the aforementioned course units.

The intervention was made through the application of teaching-learning approach using problem-based learning (PBL), more specifically, the seven-step model proposed by Schmidt (1983). Figure 1 presents a summary of the works developed during the action research.

Figure 1 – Summary of the work developed during the research



Fonte: Cordova (2018)

According to the proposal shown in figure 1, the teaching-learning activities carried out had three central objectives: to promote understanding of the social impacts of Software Engineering, meeting the requirements for humanistic and social formation provided for in the National Curricular Guidelines (2011) for students courses in the field of computing; promote understanding of the interdisciplinary epistemological relations between Software Engineering and other areas of knowledge and; carry out practical experiences on the knowledge constructed by the students. Each of these objectives was met by one or more tutorials.

To measure the effectiveness of the intervention performed, it was proposed to create an instrument to assess interdisciplinary understanding about software engineering. This instrument, which was materialized in the form of a structured questionnaire, aimed to assess whether students developed an understanding that went beyond purely technical boundaries and reached an understanding of the social, ethical, political and aesthetic impacts that their productions in this area can generate in the context in which they find themselves.

The questionnaire was composed of two dimensions: the understanding of the social impacts of software engineering and; the understanding of the interdisciplinary epistemological relations between this area and other sciences. As it aims to evaluate the interdisciplinary competences and systemic thinking of the students, it was decided to formulate questions that, following the precepts of Edgar Morin (2002), prioritized: the reconstruction of the **complex** at the expense of **simplification** by the **reductive** method and **linearity** ; the contextualization of knowledge at the expense of abstraction resulting from the atomization process; resume the multidimensionality of real-world objects as a principle.

Table 1 shows the relation between the questionnaire and the theoretical framework that guided this work, as well as the dimensions and categories into which it is divided.

Table 1 – Relation between questionnaire and theoretical framework

Dimensions	Categories	Theoretical framework
Understanding the social impacts of Software Engineering	Awareness of the importance of scientific formation;	(BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2011, p. 5); (BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2011, p. 8); (BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2016, p. 3); (SWEBOK, 2004, p. 224-256);
	Awareness about the environmental and social impacts of technological productions in software development;	(BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2011, p. 5); (RIOS, 2009, p. 16); (SWEBOK, 2004, p. 224-256);
	Entrepreneurial spirit and ethics when proposing new solutions;	(MORIN, 2002, p. 40-41); (RIOS, 2009, p. 16); (BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2011, p. 5); (BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2011, p. 2); (BRASIL, Conselho Nacional de Educação. Diretrizes Curriculares Nacionais para os cursos de graduação em computação, 2016, p. 3); (SWEBOK, 2004, p. 224-256);
Interdisciplinary epistemological relations between Software Engineering and other areas of knowledge	Relation between Software Engineering and Mathematics;	(JANTSCH, 1970, p. 14-20); (CARNEIRO LEÃO, 1991, p. 7-8); (SWEBOK, 2004, p. 257-278);
	Relation between Software Engineering and Applied Social Sciences;	(JANTSCH, 1970, p. 14-20); (CARNEIRO LEÃO, 1991, p. 7-8); (SWEBOK, 2004, p. 133-147); (SWEBOK, 2004, p. 174-190); (SWEBOK, 2004, p. 206-223);
	Relations of Software Engineering and the Human Sciences;	(JANTSCH, 1970, p. 14-20); (CARNEIRO LEÃO, 1991, p. 7-8); (KASHFI; NILSSON; FELDT, 2016, p. 3); (CARDOZO E SILVA, 2014, p. 26); (SWEBOK, 2004, p. 32-49); (SWEBOK, 2004, p. 174-190);
	Interdisciplinary relations between software engineering processes;	(JANTSCH, 1970, p. 14-20); (CARNEIRO LEÃO, 1991, p. 7-8); (SWEBOK, 2004, p. 148-161); (SWEBOK, 2004, p. 82-103);

Source: Cordova (2018)

Regarding the form of evaluation of the questionnaire, as it consists of multiple-choice questions with a nominal scale, each question was formulated to allow only one correct answer. In addition, as already mentioned, the questionnaire was divided into two dimensions, each with 6 (six) questions, corresponding to 50% of the total score to be achieved.

In this research, four levels of understanding were considered, materialized in four evaluations, which are: excellent, good, satisfactory and unsatisfactory. Figure 2 presents these evaluations and their relation with the score achieved in the questionnaire.

Figure 2 – Score scale vs Evaluation

Source: Cordova (2018)

In order to obtain a comparative reference and identify other variables that could influence the construction of the interdisciplinary competences expected from the students, 3 different groups were analyzed from the questionnaire application, being: students who went through the PBL; graduates from the years 2016 and 2017, who had no contact with the PBL; initial phase students: students regularly enrolled in the second, fourth and sixth phase of the Information Systems course in the year 2018.

When comparing the results of the questionnaires applied to these three groups, it was intended to show whether the teaching-learning process applied through the PBL had an effect on the construction of interdisciplinary skills of academics in the first group. This research went through the analysis and was approved by the Research Ethics Committee (REC) of the Alto Vale do Rio do Peixe University. The approval opinion number is 2,820,264.

Discussion and results

After applying the questionnaire, 62 responses were obtained from a population composed of 82 subjects. Table 2 shows this scenario in more detail.

Table 2 – Number of responses per analyzed group

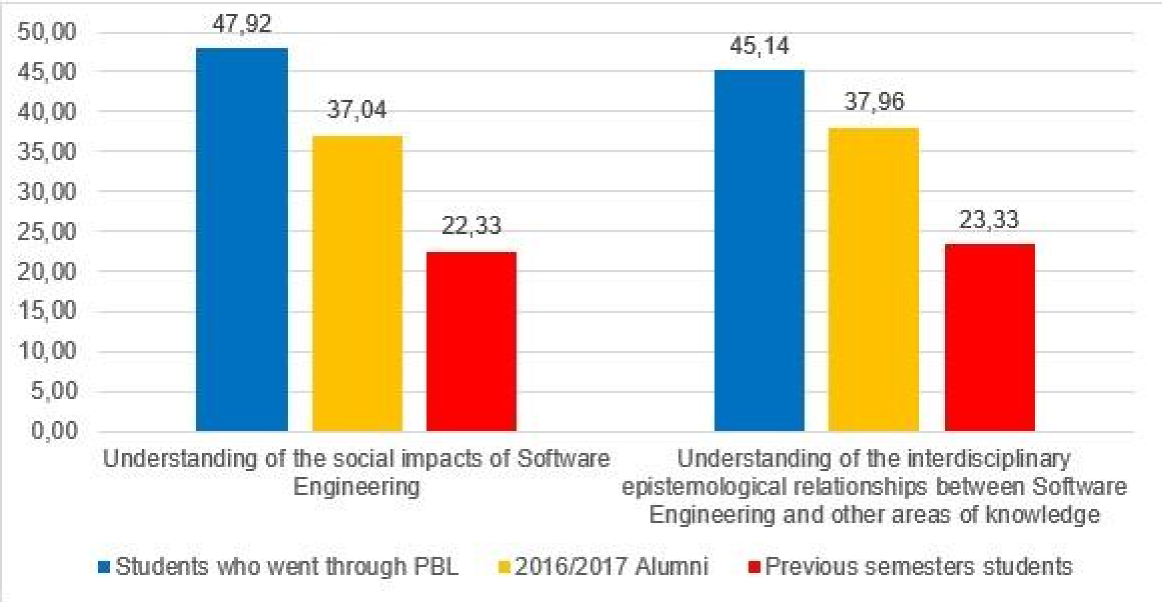
Group	Number of Expected Answers	Number of Answers Obtained	Percent Obtained
Students who went through the PBL	13	13	100%
Graduates of the years 2017 and 2018	27	20	74%
Students in the early stages	42	29	69%

Source: Research data (2018)

Through the academic management system of the institution where the present research was conducted, it was possible to survey the amount of responses expected for each group.

Regarding the dimensions proposed in the questionnaire, the scores achieved by each of the groups are shown in figure 3.

Figure 3 – Score of groups studied by dimension



Source: Research data (2018)

As it is possible to observe, in both dimensions evaluated, the students who went through the PBL achieved better performance. This is most evident when considering the overall score by adding the two dimensions. In this case, we have the following scenario: students who went through PBL with 93.05 points; 2016/2017 graduates with 75.00 points and; students of the initial stages with 45.67 points.

Given the results presented, Table 3 shows the groups studied and the evaluations they reached, respectively.

Table 3 – Evaluation obtained by each group

Group	Score	Evaluation
Students who went through PBL	93,05	Excellent
Graduates of the years 2017 and 2018	75,00	Good
Students in the early stages	45,67	Satisfactory

Source: Research data (2018)

It is important to note that the difference in scores and, consequently, in the evaluations achieved is quite significant. This shows that, considering the groups studied, the PBL combined with an adequate planning and conducted according to the guidelines proposed in this work, had a very evident effect on the construction of the intended competencies.

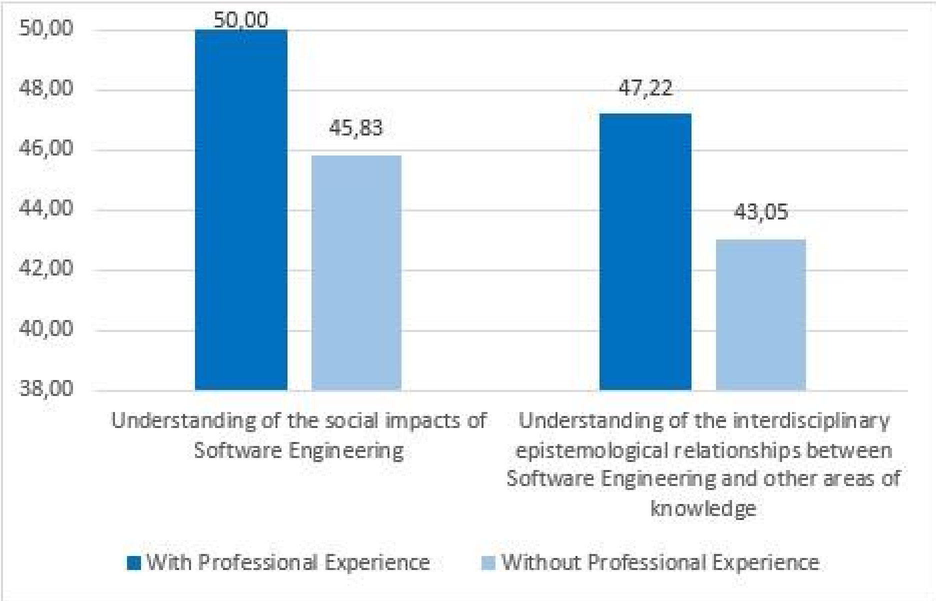
However, there is one factor that must be taken into account when analyzing the results obtained: the effect of professional experience. This is because professional experience allows, in some cases, direct or indirect interaction with professionals from other areas of knowledge. This can favor the construction of relations and knowledge that help to promote a more comprehensive understanding, to a greater or lesser degree, about the area of expertise.

Therefore, students who informed, when answering the questionnaire, that they were working in some of the areas of software engineering, were considered to have professional experience. In this context, the area of software engineering is understood as those that imply the necessary efforts for "the development, operation and maintenance of software"[9] (IEEE, 1990, p. 67). In addition, the areas foreseen in the *Software Engineering Body of Knowledge* (SWEBOK) were also considered as reference.

The influence of professional experience on the results of the group that went through PBL can be seen in figure 4. In this group, 46% of the interviewees said they were working in some of the areas of software engineering.

[9] "o desenvolvimento, operação e manutenção de software"

Figure 4 – Influence of professional experience on the results of students who went through PBL



Source: Research data (2018)

Observing the results, it can be evidenced that, although there is a clear difference between the score reached by those who worked in some of the areas of software engineering, in relation to those who did not work, the score of each subgroup does not deviate more than 5 points from the main group average in both dimensions. In addition, considering the evaluation established to classify the results obtained from the questionnaire, both maintained the evaluation as **excellent**.

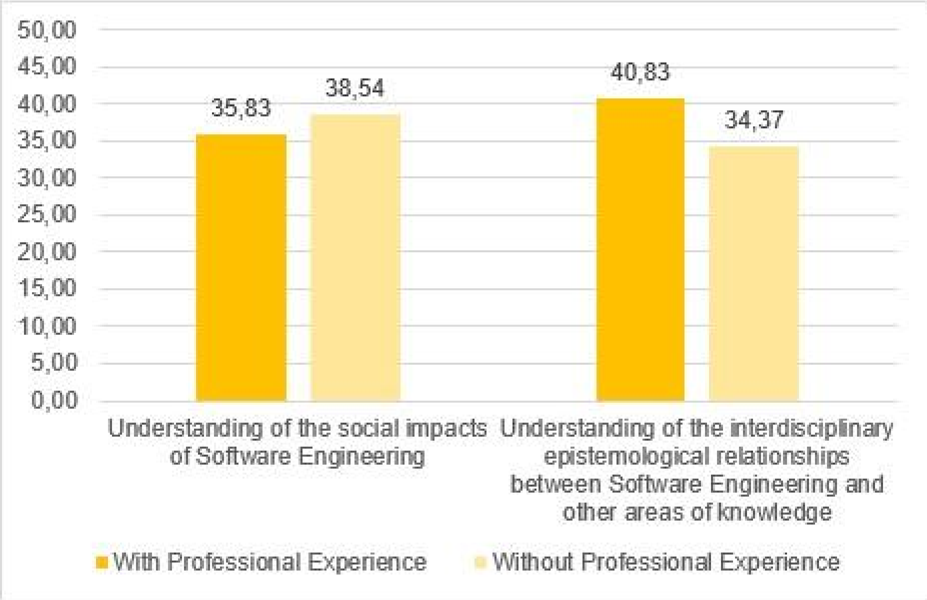
Likewise, it can be seen that, in this group, students who claimed to have professional experience achieved a better performance in both dimensions analyzed.

The group of graduates from 2016 and 2017, in turn, obtained results that differ slightly from the group that passed through the PBL. The percentage of the sample that claimed to have professional experience in the group of graduates is 50%, which does not differ significantly from the first in this regard.

However, it was expected that professional experience would help to improve the score of the groups in both dimensions. Despite this, the 2016/2017 graduates who declared they had professional experience scored less in the dimension that assesses their understanding of the social impacts of software engineering.

Figure 5 shows how this experience influenced the score of the group of graduates.

Figure 5 – Influence of professional experience on the results of graduates from 2016 and 2017



Source: Research data (2018)

It can be assumed that these results are due to the overly technical characteristics required of these professionals in the job market. But further research is needed to confirm this hypothesis.

Regarding the evaluations obtained, in the same way as in the group of those who went through PBL, both those who were having professional experience and those who were not, despite the difference in scores, maintained the same concept as the main group.

Finally, when observing the group of students from the initial stages, where 17% of the interviewees had professional experience, another difference can be seen in relation to the other groups. In the latter, as can be seen in figure 6, the variation in scores between those who declared they had professional experience and those who declared they did not have it is even more significant.

This group is formed, for the most part, by students who have gone through few curricular units and, therefore, are endowed with less practices and class hours. As a result, these students do not have the same skills already developed by the other two groups.

This characteristic showed that those who had professional experience had a significant advantage. For example, there was a greater variation in relation to the average of the main group, both in the subgroup of those who had no professional experience, which had its concept lowered to **unsatisfactory**, and in the subgroup of those who had it, whose concept was increased to **good**.

Figure 6 – Influence of professional experience on the results of students in the early stages

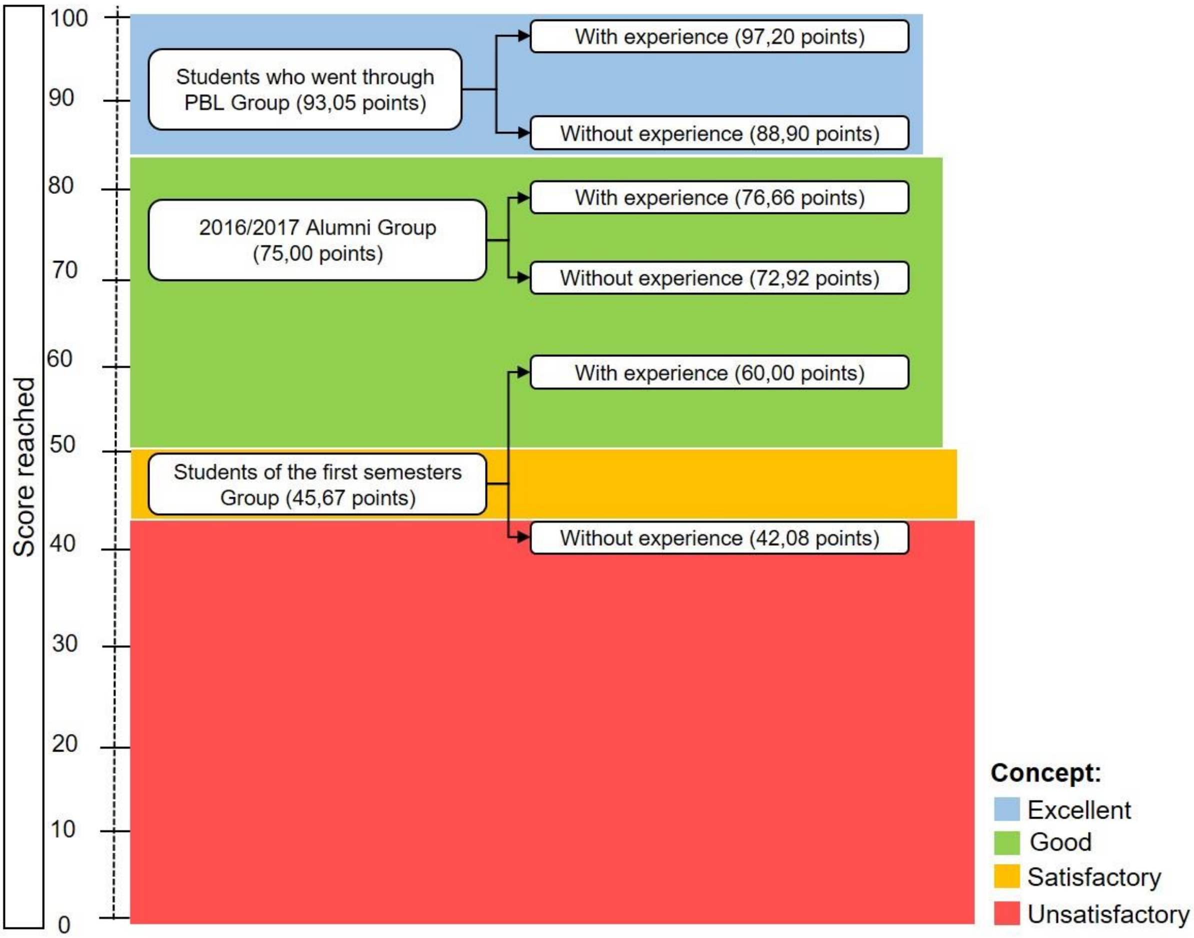
Source: Research data (2018)

It can be seen in figure 6, that with or without professional experience, the results obtained by the group composed of students from the initial phases remain way below the other groups in both dimensions. It is important to highlight, for example, that the best score achieved by this group does not reach the worst score in the group of graduates, who reached the second-best concept. Even greater is the difference compared to the group that went through the PBL.

This highlights the importance of the skills developed during the undergraduate course, especially considering the teaching-learning method proposed in this work.

Thus, to better demonstrate the differences in punctuation between the groups analyzed, figure 7 presents a synthesis of the variation of concepts and the influence of professional experience on the results obtained for each group and subgroup, considering the sum of the two dimensions.

Figure 7 – Score/evaluation synthesis and influence of professional experience



Source: Research data (2018)

As it is possible to observe, only in the group of the initial phases does a change in the concept of the subgroups in relation to the main group become evident due to the influence of professional experience. In the other groups, this variable did not have a significant impact.

Given the above, it is possible to conclude that the professional experience contributed to the development of the interviewees' understanding, in the three groups and in both dimensions evaluated. However, it was not decisive for a significant rise in the general concept of each group.

In addition, it can be seen that only students who had PBL, as it was conducted, in their formative process - even those who do not have professional experience - obtained an excellent concept. This allows us to infer that the technique adopted was effective for what it was proposed: to form citizens with greater awareness about the social impacts of their activities and endowed with a better understanding of the interdisciplinary bases of their area of activity.

These competencies are aligned with the conceptions of education assumed to be true in the execution of this work and with the definitions of Carneiro Leão (1991) and Jantsch

(1970) for interdisciplinarity, since they enable the student to understand the application of Software Engineering for the resolution of real problems, whether for marketing, scientific or social purposes, therefore, with a common purpose or axiomatic to the knowledge to be applied. In this context, the practical use of the principles defined by Schmidt (1983) for PBL, together with a teaching plan about the formulation of the problems and the contents to be worked on, enabled the success evidenced through the data of this research.

This scenario makes it possible to state that, as in other areas such as medicine, accounting, administration, etc., software engineering can also benefit from PBL, when properly applied. Thus, answering the central question of this research, it can be said that yes, PBL contributes to an interdisciplinary training process in Software Engineering, aiming at a comprehensive education.

However, it is important to emphasize that, although the technique was an important enabler for the success of the teaching-learning process, planning and teaching work, according to Dalben (2013), are the determining factors of this success. Equally important is the engagement of students in the process of actively seeking knowledge.

Final considerations

The results presented in this work allow us to conclude that PBL consists of an effective medium, whose principles and practices, added to a planning, content and processes properly conducted by the teacher, allows satisfactory results to be achieved in the formative process in Software Engineering. Through this technique, it was possible to lead students through an interdisciplinary teaching-learning process, which culminated in the development of the expected skills.

However, it is important that the processes developed in this research are replicated in other contexts - classes from the same course or from other educational institutions -, not only to promote the continuity of the improvement work in the formative process, but also to resolve issues encountered during the execution of this research, such as the one observed in figure 5, where it is evident that the graduates of 2016 and 2017 with professional experience scored less in questions related to the dimension that assesses the understanding of the social impacts of Software Engineering.

This result may be the result of overly technical professional performance. For this reason, new research and reflections on how the world of work has influenced the formation of human capital are also necessary to confirm or refute this hypothesis. In addition, the comparison with different results of the application of the technique proposed in this work is important to validate or not the results achieved in this work.

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