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AVALIAÇÃO DA ESTRATÉGIA DIDÁTICA DE APRENDIZAGEM BASEADA EM PROBLEMAS: APLICAÇÃO NO ENSINO SUPERIOR

ASSESSMENT IN PROBLEM- BASED LEARNING: AN APPLICATION TO HIGHER EDUCATION

EVALUACIÓN DE LA ESTRATEGIA DIDÁCTICA APRENDIZAJE BASADO EN PROBLEMAS: APLICACIÓN EN EDUCACIÓN SUPERIOR

Alexander Mejía-Camacho[1]; Sulma Paola Vera-Monroy[2]; María Cristina Gamboa Mora[3]; Jorge Wilson Torres Hernández[4]

[1] Universidad de Cundinamarca - amejiac@ucundinamarca.edu.co
[2] Universidad de La Sabana - sulmavemo@unisabana.edu.co
[3] Universidad Nacional Abierta y a Distancia - maria.gamboa@unad.edu.co
[4] Universidad de las Américas y el Caribe - jtorres@unac.edu.mx

Resumo: O artigo apresenta os resultados de um projeto de pesquisa que teve como objetivo avaliar a implementação da estratégia didática "Aprendizagem Baseada em Problemas". A pesquisa foi realizada em uma universidade colombiana, na disciplina de Biomateriais do programa acadêmico de Engenharia Biomédica. A população de estudo foi composta por 106 alunos, dos quais 46 integraram o grupo experimental e 60 o grupo de controle. O grupo de controle trabalhou com estratégias tradicionais e o grupo experimental implementou a estratégia em três estágios: planejamento, caracterização e prototipagem, emulando as propriedades mecânicas de materiais comerciais. Vídeos dos protótipos sendo testados no simulador foram filmados, marcadores de desempenho foram estabelecidos e pesquisas foram aplicadas para reconhecer as habilidades adquiridas. As médias das perdas acadêmicas dos dois grupos, controle e experimental, foram comparadas, a significância foi testada com o teste estatístico paramétrico T-test. Conclui-se que o prejuízo escolar diminuiu, o aprendizado aumentou, os tópicos foram reforçados e a motivação aumentou. Os principais obstáculos que enfrentaram foram: gestão do tempo, pouca organização, e a ideia de que partilhar tarefas é o mesmo que trabalhar em equipe.

Palavras-chave: Solução de problemas; Aprendendo; avaliação; estratégias de ensino; ensino superior.

Abstract: This article presents the results of a research carried out in a Biomaterials course from the Biomedical Engineering program in a university in Colombia. The research assessed the implementation of the didactic problem-based learning strategy. The study population was made up of 106 students: 46 students from the experimental group and 60 students from the control group. The experimental group implemented the strategy in three stages: The first one, named planning stage, focused on the theoretical construction for solving the problem. The second stage attended to the characterization, where it was necessary to perform mechanical tests on the proposed instructional materials with the intention of evidencing the relevance for the proposed use. The last stage, named the prototyping, focused on the construction and testing of each prototype developed by each team. Subsequently, this allowed defining performance indicators as well as the application of surveys for acquired skills. Then, academic loss averages were compared. It is concluded that academic failure decreased, learning increased, positive reinforcement of topics raised and motivation boosted significantly. Finally, it was found that the main issues that students faced were: time management, poor organization and the belief that sharing tasks is the same as team-working.

Key words: Problem solving; learning; assessment; teaching strategies; higher education.

Resumen: El artículo presenta los resultados de un proyecto de investigación que tuvo por objetivo evaluar la implementación de la estrategia didáctica “Aprendizaje Basado en Problemas”. La investigación se llevó a cabo en una universidad colombiana en la asignatura de Biomateriales del programa académico Ingeniería Biomédica, la población objeto de estudio estuvo conformada por 106 estudiantes, 46 estudiantes

constituyeron el grupo experimental y 60 el grupo control. El grupo control trabajó con estrategias tradicionales y el grupo experimental implementó la estrategia, en tres etapas: planificación, caracterización y elaboración de prototipo emulando las propiedades mecánicas de los materiales comerciales. Se filmaron videos de los prototipos siendo ensayados en el simulador, se establecieron marcadores de rendimiento y se aplicaron encuestas para el reconocimiento de las habilidades adquiridas. Se compararon los promedios de pérdida académica de los dos grupos, control y experimental, la significancia se probó con la prueba estadística paramétrica T-test. Se concluye que disminuyó la pérdida académica, se incrementó el aprendizaje, las temáticas se reforzaron y aumentó la motivación. Los principales obstáculos a los que se enfrentaron fueron: el manejo del tiempo, la poca organización y la idea sobre que repartir tareas es igual a trabajar en equipo.

Palabras clave: Resolución de problemas; aprendizaje; evaluación; estrategias de enseñanza; educación superior.

1. INTRODUCTION

Assessment is the most important process to spot the effective functioning of the educational system, in which direct and systematic observation is necessary, and through which teachers assess the learning processes as well as their own educational practice. In this regard, Navaridas (2002) considers assessment as an effective procedure to assemble information and inform decisions making later on, with the object of improving educational practice and achieve quality learning at university. In addition, Castillo-Arredondo and Cabrerizo-Diago (2006) suggest that the priority function of the assessment should be the orientation of the teaching-learning process for decision-making based on the obtained results, which allows correcting the shortcomings arising during the process. Moreover, when educational strategies are conceived as aimed actions through a daily work of improvement and responsibility along with cognitive, metacognitive, motivational and behavioral elements (MONTES et al., 2018), their assessment will be linked to learning outcomes, commitment and teaching support.

The quality of the education system is shown in the performance of the students as the observable behavior of the aforementioned actors. It is at this point, where the need arises to come up with didactic strategies that promote metacognitive skills and processes, as a means to recognizing how academic success is obtained in the classroom experiences and how the strengthening of these have an impact on the development of professional skills. All of these aspects are rendered into teaching effectiveness as a result of a direct implementation of the didactic strategy (DARLING-HAMMOND et al., 2017). Additionally, Estrada (2016) states that in the university context, it is necessary to include strategies that allow the implementation of all the key competencies, aiming to achieve better personal and professional results. Experiences on the implementation of strategies focused on research, in pursuit of competencies, pointing out that the solution to emerging problems in their corresponding spheres of action brings on a solid training, both academically and professional area. (ÁLVAREZ-VILLAR et al., 2016).

In the Biomedical Engineering program of the University in Bogotá (Colombia), the course called Biomaterials corresponds to a subject of the disciplinary component, strongly framed in the concepts of the basic sciences component, which makes its teaching a

complex process and with hard-to-achieve results. During the course, there has been evidence of demotivation, partial appropriation of concepts and poor performance, which leads to a considerable academic failure. With the aim of achieving efficient academic processes, the university has tried to introduce new teaching strategies in the classroom to strengthen the teaching-learning process, seeking to replace teaching practices of knowledge transmission by actions that promote autonomy and application of in contextualized problems. It is considered that a didactic strategy is relevant insofar as it promotes cognitive abilities; conceived as the operational thinking, by means of which the subject can make contents its own as well as the process that was implemented for it (BRAVO-BOWN ET AL., 2016).

From an educational perspective, cognitive skills are the required tools to build and reconstruct knowledge, which lead to the identification and transformation of information into knowledge, for which the development of cognitive processes is necessary (CAPILLA, 2016). These processes can be simple or complex, both conjugates lead to the definition of cognitive domains such as knowing, applying and reasoning. In the words of Puente-Serrano et al. (2009), to know, to know how and to create. In order to comply with the above-mentioned purposes, in some subjects of the program, there is a component called research in the classroom whose objective is to strengthen the skills needed to achieve research competence, in agreement with what was stated by Álvarez-Villar et al. (2016), associated with the ability to solve problems, the willingness to formulate them and produce innovative alternatives for understanding, allowing students to face their training with a research sense (CASWELL, 2019).

The Project Based Learning -PBL- from now on, seeks that students and teachers work together during an active process by which they investigate, plan, decide, implement and assess problems which not only have an application in their professional environment but also can be addressed from the classroom (DICKINSON et al., 1998; CORREDOR-TAPIAS & ROMERO-FARFÁN, 2007), allowing educational agents to be conceived as equals, striving to improve the attitude of the two towards the teaching-learning process, stimulating a collaborative work that lead to the significant construction of knowledge as to the topics presented within the course syllabus (FIGUEROA et al., 2008). Currently, many schools have implemented the PBL as their teaching strategy, from the basic semesters of their programs, offering students varied tools to propose, argue, execute, build, defend ideas and concepts of their area, which they have applied throughout their training period, guaranteeing a permanent construction of knowledge and a strong appropriation of information (JOFRÉ & CONTRERAS, 2013; GARMENDIA et al., 2014).

Dickinson et al. (1998), depicted the features of the PBL methodology as a student-centered strategy, directed by themselves, where they build their new knowledge from previous ideas collected throughout their experiences and other learning concepts, newly learned within the classroom. Also, formulation of questions represents the vehicle to develop skills and exhibits different degrees of complexity, depending on the achievements and competencies that are to be achieved within the course objectives. In this sense, the

teacher proposes the project that the students should carry out, and in which they must define the problem situation, describe the purpose of the problem and establish the assessment criteria.

Consequently, during the application of the project and during tutorial sessions, the teacher must formulate questions aimed at solving doubts arose within the implemented strategy, instructors should never give the specific answer, given that the students are responsible for the knowledge and they are the ones who must get answers, find and propose solutions (JOFRÉ & CONTRERAS, 2013). Institutions can implement PBL using the pure model, in which PBL projects are applied throughout the training process, or the hybrid model, where traditional strategies and some modules or themes are applied under the PBL strategy (LABRA et al., 2011). When new strategies or learning methodologies are implemented, it is necessary to be able to assess the results in terms of different variables or indicators which determine the effectiveness of the processes. According to Alves (2008), indicators are essential to measure the change or transformation that has taken place, which should allow a diagnosis, validation of progress, skills gained by the student and identification of problems (CARDONA & SÁNCHEZ, 2010). Within the research process, the following educational indicators are established, to accompany the traditional indicator of academic performance expressed in terms of approved and failed grades, according to a pre-established scale.

The word motivation comes from the Latin "movere" that represents movement, it has to do with the willingness to perform a certain action. In 2011, Orhan and colleagues established that motivation refers to the process that guides and supports the behavior and performance of people. It can be understood that being motivated shows the willingness that a person has to perform an activity, added to the potential interest that has to complete it and the desire to do it in a specific time. Motivation is considered a multidimensional feature, fueled by factors such as: need, impulse, action and reward. According to Ryan and Deci (2000), there are two types of motivation, intrinsic and extrinsic motivation. Intrinsic motivation refers to performing an action without receiving an apparent reward different from the activity itself and extrinsic motivation occurs when an activity is performed with the purpose of obtaining an external reward.

The motivation eases the interaction between the teacher and the students through the contents, activities, evaluations and strategies. It is considered that a student is motivated when the contents are related to their interests, when they understand the explanation and get satisfaction in learning, when they master the subject and obtain good grades, and also if they receive consistent recognition with the effort and the invested commitment in developing the activity (RYAN & DECI, 2000).

The fundamental purpose of education is to train people in new knowledge required to perform in a particular field, being the crosscutting objective at all academic levels, from primary school to postgraduate studies. The way to demonstrate the acquisition of new knowledge by students is through the assessment processes involving different dimensions which not only fall on the teacher, but also the entire academic community (FLORES, 2010).

There are different assessment strategies and all of them tend to improve the teaching-learning processes, adjusting to the three basic steps: collecting information about learning, applying quality criteria and making judgments. These aspects can be focused on different points, such as: deriving grades, guiding students to improve their performance, determining difficulties, evaluating teaching methods and motivating to give continuity to the processes (DORREGO, 2006), this assumption is supported by Svihla and collaborators, who determined that an efficient way to assess learning performance is through practice (SVIHLA et al, 2019).

Pineda and collaborators in 2014, showed that student commitment is directly related to academic performance, realizing that students develop a high level of commitment to their academic process and their subjects if they face enriching experiences which stimulate their intellect and strong desire for learning (PINEDA-BÁEZ et al., 2014). The commitment by the student promotes the development of skills, willingness and habits, essential axes during the academic process that substantially can improve the acquisition of knowledge and therefore the results (CARINI et al., 2006).

At present, the teaching support is defined in terms of the shared work action between the teacher and the student. The teacher assumes a collaborative role that guides the learning process; the function that a teacher is required to assume in the classroom must be defined in accordance to the needs of the class and the group of students, with the only purpose of learning. Slavin in 2003, showed that effective performance or teaching is related to: didactic skills, teaching styles, teaching models, demonstrating that students obtain more achievements when the teacher accompanies their processes, emphasizing specifically on: highlight academic goals, organize carefully the contents, explain the objectives of learning, provide feedback on the topics, promote moments to practice the concepts learned and correct mistakes in a clear and effective way (SLAVIN, 2003).

The reinforcement of topics during the teaching process is another relevant aspect because it manages to consolidate what has been learned; improving the interrelation between new concepts and the ones assimilated within the school context or in everyday life. The teacher role as a mentor has demonstrated a positive impact not only on academic achievement but also on learning environment in the classroom (HARTMAN et al., 2018).

From this point of view, it is possible to consolidate as a decisive moment of learning. There are different works in which this indicator is taken as an important factor to evaluate the relevance of a teaching proposal, based on a knowledge construction guided by the teacher and focused on the student. This indicator can be used to identify two relevant aspects: Integrality, understood as the facility that exists to relate concepts with previously acquired themes and the Extensibility shown by the existing projection to reinforce future processes in which it is necessary to resort to the learned concepts. (MAHMUD & GUTIÉRREZ, 2010).

Currently many research groups (PAINEÁN et al., 2012; JOFRÉ & CONTRERAS, 2013; HUDSON-VIZCAÍNO, 2015; EI-HAY-ABD & ABD-ALLAH, 2015; GORGHIU et al., 2015; AWANG & DAUD, 2015; PAREDES-CURIN, 2016; CULCLASURE et al., 2019; WARR & WEST, 2020),

make progress in the implementation of the PBL strategy to achieve an increase in the quality of the learning they get from their courses, finding significant increases in the development of skills in pursuit of learning: observation, assertive communication, teamwork, reflection, problem solving, and independent learning, in numerous courses in human and exact sciences studies.

The contribution of this article is to provide an answer to the research question to the community: How does the implementation of the teaching strategy (PBL) impact educational performance indicators within the teaching-learning process at the university level?

2. METHODS

The project was developed with a group of 46 students, 44% men and 56% women, between the ages of 19 and 31 years who studied the subject called Biomaterials, students that made up the experimental group. As a control group we worked with a population of 60 students, 57% women and 43% men, with ages between 18 and 25 years, who participated in the subject in the previous academic period. Biomaterials is a theoretical subject of the disciplinary component of the Biomedical Engineering program, it is located within the curricular grid in the seventh semester and it has the basic subjects as previous knowledge: General Chemistry, Organic Chemistry, Biology and Biochemistry. The general topics of the curriculum are crystallography, mechanical properties, classification of materials, conformation of materials, immunology, compatibility and tissue engineering. The main objective of the course is to build up knowledge about the fundamentals, classification, properties, manufacture and application of different materials used in biomedical. It is worth mentioning at this point that with significant progress in new technologies, this course pretends to incorporate simulation technology for training student as a valuable addition to traditional teaching methods.

In this sense, students employ Noelia which is a simulator for Gynecology (figure 1), it is used to emulate giving birth and to assess the conditions related to labor. Within the implements that make up the simulator, there are components that deteriorate with use, known as supplies; devices that, due to its poor condition, prevent the measurements from being correct, generating erroneous simulations. One of these components is the birth canal, a piece of elastic material that resembles the channel through which the unborn child passes, from the uterus to the uterus. Outside, this piece is essential for the operation of Noelia, for this reason, make a copy and dispose of it would be beneficial for the laboratory. Through the strategy (PBL) The project proposed to the students to design a functional piece, similar to the birth canal, with the shape and mechanical properties required to emulate the mechanical properties of commercial materials. The strategy was developed under the integration of three stages: the first one named planning, the second one called characterization and the third one that corresponded to the development of the prototype.

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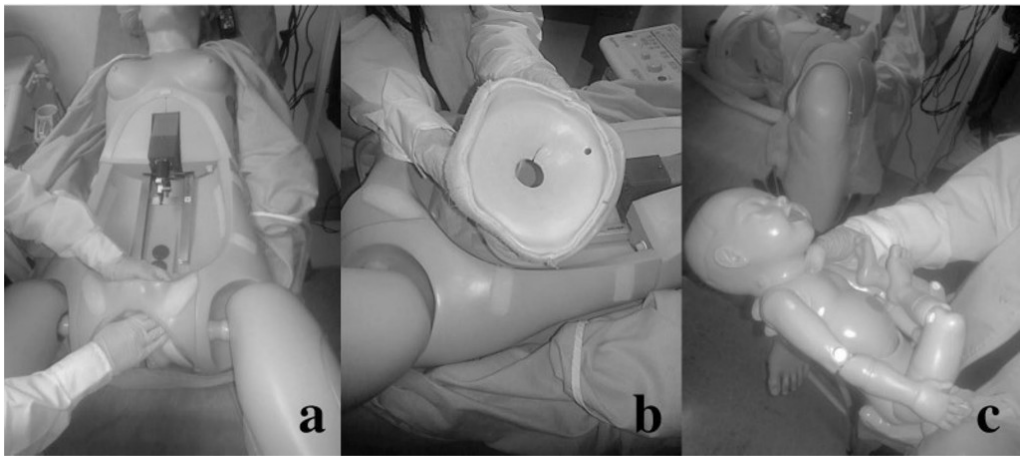

Figure 1 - Childbirth simulator Noelia.
Note. a) Noelia b) Birth canal c) Neonate

At each stage of the implementation of the PBL strategy, the coherence of the proposals presented by the students, the development of the activities, the presentation and exposure of the respective products were assessed. As an evidence of this, videos of the prototypes were being tested in the simulator and surveys were applied, adapting the methodology of Paineán et al, (2012). As a result, information was collected in terms of students 'experience during the development of the project, finally, the results were compared with the control group and it was established the impact of the PBL.

To complement the strategy assessment process, the participants of the experimental group recognized the skills strengthened during the process as well as the problems of the implementation from the metacognitive processes. Finally, the percentages of academic failure of both groups were compared against each other.

3. RESULTS

In the planning stage, the groups made the bibliographic review to appoint the material that would comply with the optimal flexibility and elasticity characteristics to make the piece. Also, they determined the material of the mold and the form of molding that would comply with the requirement of demolding easily without affecting its integrity. Finally, they modeled the prototype in a layout, using appropriate design tools, establishing the dimensions and geometries of the piece. At this stage, students were expected to develop the following activities: search the internet for information, write paragraphs, write methodologies, compile information from other classmates. At the end of the first examination date, the group handed in a document with the information about the chosen material for the piece, the material of the mold, the form of molding and the modeled piece (figure 2).

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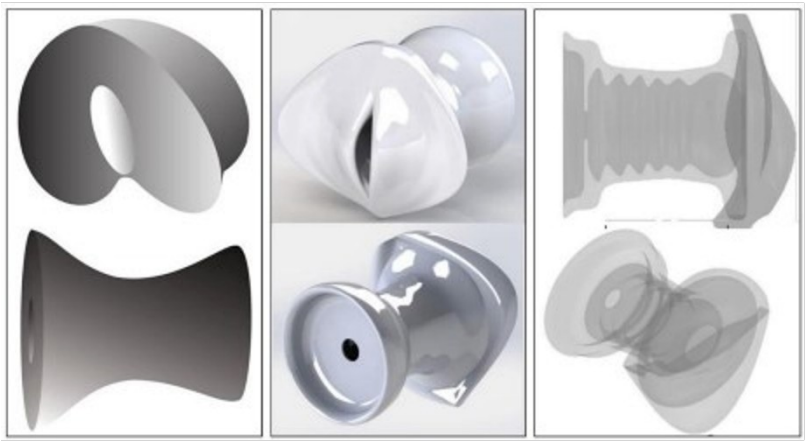

Figure 2 - Digital models of the birth canal made by the students.

In the characterization stage that was developed during the second examination date, the groups constructed specimens with the selected material and carried out mechanical tests in order to characterize it and determine its usefulness with respect to the properties required for the prototype, what is more, at this stage they formed the mold. The proposed activities to be developed by the students at this stage were: search for internet information and texts, write paragraphs, compile information and paragraphs from other classmates, buy materials, make molds, tabular data, develop mathematical calculations, write conclusions, graph, make samples for tests, take pictures and perform tests (figure 3). At the end, they delivered a document with the assessment of the mechanical properties along with conclusions about the relevance of the material, including the images of the shaped mold.

Figure 3 - Molds of the birth canal made by the students.

In the third stage that corresponded to the making of the prototype, the students constructed the model and socialized their results (figure 4). As a final test, the functionality of the piece was assessed as a delivery channel in the simulator. The strategy of PBL implemented in the three stages in correspondence with the postulates of (JOFRÉ & CONTRERAS, 2013; GARMENDIA et al, 2014) allowed participants to use tools to propose, argue, build and defend ideas and specific concepts to their area of interest to solve the challenge.

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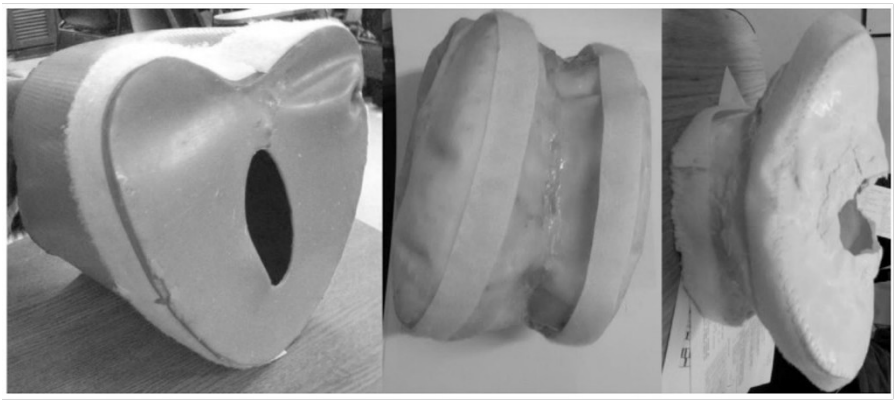

Figure 4 - Prototypes of the birth canal performed by students.

Regarding the activities carried out by the students in each stage of the project (figure 5), a high commitment to their implementation and an active participation were evidenced, however, the fact of developing the activities did not guarantee the achievement of the objectives at the end of each stage, since some groups of students who said they had carried out all the proposed activities, did not get the expected results. When looking for an explanation of this phenomenon, it was found that: some of the activities were not carried out according to the given instructions, this is shown more clearly when students badly estimated the time to develop each activity, finding that only 7.0% of the students did the total of the proposed activities in each stage, the others, developed some activities of each stage (16.3 %) or participated simultaneously in activities of various stages (76.7 %) (Table 1). From the point of view of teamwork, assuming roles within the group can be taken as an indicator of organization (GÓMEZ-MUJICA & ACOSTA-RODRÍGUEZ, 2003). Despite this perspective, teamwork was not evident as a strength within the learning process developed with the experimental group, due to the lack of enough seriousness and commitment in some students to face the tasks, perceiving a reduction of the abilities that it was expected to strengthen in each student as a result of the proposed work. It was found that some groups required more time to achieve their objectives, and in some cases, it was necessary for the groups to think over the methodologies they had proposed.

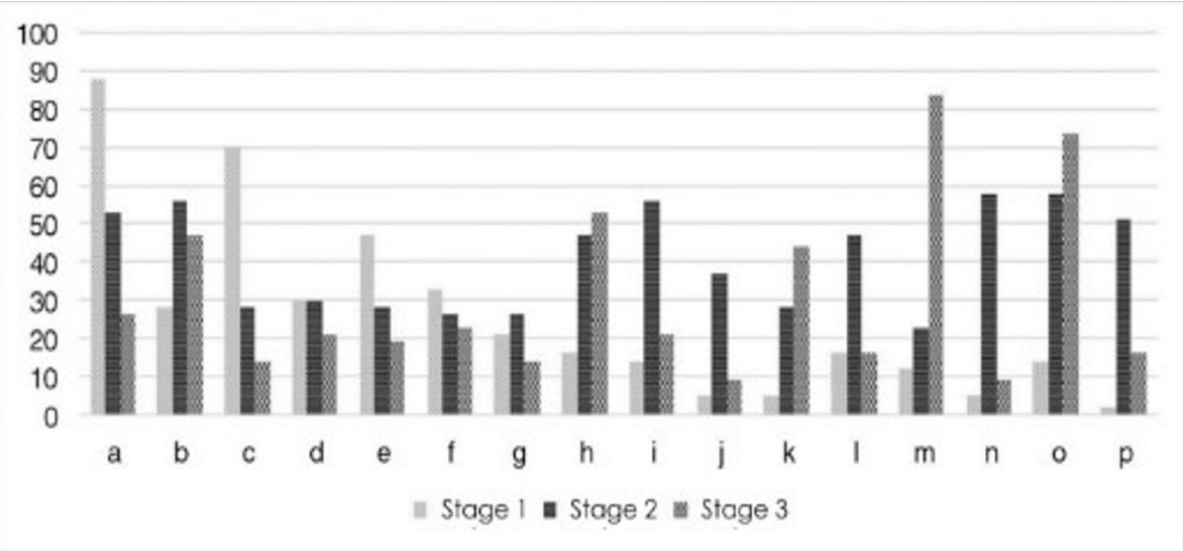

Figure 5 - Percentage description of the activities carried out by the students during each stage of the implementation of the PBL strategy.
Note. (a) Searching for information from the internet (b) Getting materials for prototypes (c) Searching for text information (d) Writing paragraphs (e) Writing methodologies (f) Compiling information from other groupmates (g) Compiling paragraphs from other classmates' group (h) Make molds (i) Tabulate data (j) Develop mathematical calculations (k) Write conclusions (l) Graph (m) Create prototype (n) Make samples for tests (o) Take pictures (p) Perform mechanical tests.

Table 1. Percentage of students who completed the proposed activities

Compliance with proposed activities	Students % (N = 46)
They carried out the total of activities	7.0
They did not perform all activities	16.3
They carried out activities of other stages	76.7

One of the priorities during the evolution of the project was to properly document the obstacles faced by the students during each stage. From the results (figure 6), there were 4 recognized obstacles with greater incidence by students during all stages of the project. The first corresponded to the lack of time (50.0 %), demonstrating that students put into practice, few assertive strategies of temporal planning, which affects their learning processes and outcomes, associating this results with the distribution of activities within each group, allowed to better understand the fact that some groups turned in assignments behind schedule . During the first stage, most of the students did not consider time as an obstacle, nevertheless, when they realized the delays as well as the delayed activities, they understood the importance of planning and tried to carry forward the work to finish on time.

The second obstacle was the lack of experience (40.7 %), getting a reasonable result, taking into account that the project was innovative and demanding. As shown by the fact that most students were not accustomed to being free to be builders and architects of their knowledge, they needed the guidance and permanent support of the teacher, who participated actively in the training process. Specifically, there was an emphasis mainly on the fact that the required experience was not to have prior knowledge of the project,

materials, processing or mechanical characterization, but what is really necessary was to possess skills about the processes of searching, processing, analysis and synthesis of information, which are really required to argue the constructed ideas within any training process.

The little organization was placed in third place (34.0 %), this obstacle is related to the work of the student regarding their academic activities, showing that the students did not prioritize, nor plan their tasks adequately during the course of the stages. This fact leads in problems related to the execution of activities that do not completely correspond to the proposals, also those carried out of time or worse, those which were not performed.

Finally, the lack of information (31.0 %) was a problem that had no apparent justification, taking into account that the necessary information to correctly execute the proposed activities was easily accessible, in available sources within the institution such as: books, magazines or internet. Continuing with figure 6, it was found that the highest value was in stage 1, with an evident decreasing tendency during the following stages, this behavior is explained thanks to the joint of the project with the contents of the subject, which motivated the balance between the acquired knowledge in the classroom and the development of the activity.

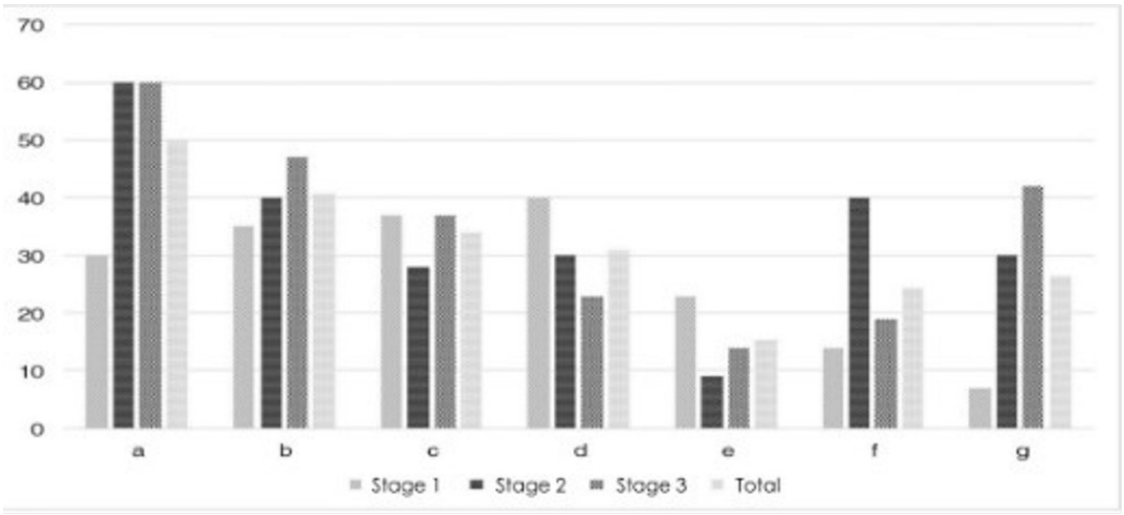

Figure 6 - Percentage description of the problems that students experienced in the implementation of the PBL

Note. *(a) Lack of time (b) Little experience (c) Little organization (d) Lack of information (e) Theoretical foundation (f) Group problems (g) Poor planning.*

Once the project was finished, the students realized the developed cognitive skills during the implementation (table 2), recognizing that solving problems was the skill with the greatest reinforcement (65.1 %). This was steady with the strategy implemented, where the students had to propose alternatives to solve the problems that came up during the stages, in addition to overcoming those problems so they could finish the project. Moreover, the students chose the ability to synthesize and write information (44.2 %), showing that the project motivated them to put into practice reading, compiling, prioritizing and writing.

Consequently, students become challenging within an PBL methodology reinforcing fundamental communication skills which are usually practiced within the subjects of the syllabus.

Proposing and executing ideas, ranked third (39.5 %), showing the development of cognitive and procedural skills are vital in any training process. What is more, this fact is significant achievement for the project, since the success of itself depended to a large extent on the ability of the students to generate a product, not only to propose a solution, but also to materialize it by means of a functional prototype, in line with what was stated by Estrada (2016).

The fourth skill chosen by the students was teamwork (20.9 %), which was crucial, considering that this ability favors the development of social skills and improves the quality of the obtained results, even though the percentage of students which chose this skill was low, showing that most of them did not perceive a strengthening of this ability, which was also seen within the results obtained in the obstacles (figure 6) and in the activities done (figure 5). Although there was little organization on the planning and development of some of the activities, in the end all the groups completed the proposed objectives.

Finally, the students chose to use the databases (4.6 %), recognizing that they improved their ability to perform effective webquests when using specialized search engines, realizing that the use of popular search engines entails problems as to quality, authenticity, reliability, authorship, among others.

Table 2. Percentage description of the cognitive skills strengthened by students

Ability	Students % (N=46)
Solve problems	65.1
Synthetize and write information	44.2
Propose and execute ideas	39.5
Teamwork	20.9
Use database	4.6

In order to assess the impact of the PBL methodology as a didactic strategy used to strengthen the teaching-learning process of the subject, students were asked to assign a value within the scale of 1 to 10, to the five educational indicators that were recognized. As performance markers: learning of new concepts, commitment to the subject, motivation, reinforcement of the topics and teaching support. The results were compared with the data of the control group, using the STATA12® program (table 3). Having in mind the postulates of Navaridas (2002), the assessment is the most effective method to collect information.

The analyzed samples were adjusted to normal according to the kurtosis measurement, so it was chosen to implement the parametric model T-test with a level of significance of 0.05, finding that there was a significant increase with respect to the group control in all the indicators, demonstrating that the PBL methodology improves the results obtained within the teaching-learning process of the subject Biomaterials, in terms of educational indicators.

In terms of learning of new concepts and the reinforcement of the themes, it can be stated that their assessment not only belonged to the assessment made by the students, but also to the continuous feedback given throughout the application and the support in each delivery. It is worth mentioning that as a consequence, students generated coherent and argued responses from theory to practice, these results showed that the implementation of the project reinforcing the learning process positively along with allowing students to appropriate new content and integrate effectively into their training processes in correspondence with the postulates of González and Castro (2011).

It is worth mentioning that the commitment to the course and motivation showed that those activities that required to argue and sustain, reinforced the feeling of belonging, commitment and responsibility, progressively throughout the project, improving the punctuality and quality of handing over requested; leading in turn to a more efficient interaction between the teacher and the students as a consequence of the motivational factor generated by the PBL strategy, in congruence with the premise of Ryan and Deci (2000).

With respect to the teaching support, it was noticed that the students perceived a positive change compared to the traditional methodology, in which the teacher guides each of the steps of the training process, keeping an eye on the student, whereas in the PBL methodology the students are to be responsible for their own process and the teacher must be conceived as a facilitator who helps to increase motivation in autonomous learning environment, constantly ensuring the welfare of students, so that they do not lose sight of the objectives helping students to achieve goals within the established times and with the requested quality. At this point, the integration of the new knowledge to the previous mental structures was achieved, strengthening the capacity to propose solutions and materialize the prototype as a determining action, adhering to what was exposed by González and Castro (2011).

Table 3. Evaluation of the contributions of the strategies implemented in the groups

Educational indicators of performance	Control group		experimental group		Variance test	T test
	Mean	Kurtosis	Mean	Kurtosis		
Learning new concepts	5.62	2.15	7.88	2.57	.448	.000
Teacher support	6.06	2.11	7.97	3.52	.273	.002
Commitment to the subject	6.97	2.17	8.4	3.29	.825	.001
Motivation	5.71	2.08	7.63	2.9	.517	.001
Reinforcement of the themes	5.71	2.04	7.48	2.48	.89	.002

Finally, the averages of academic failure of both control and experimental groups (table 4) were compared as the last indicator of performance, which allowed concluding that in the experimental group, the number of people who failed the course decreased, However, to investigate the significance of this result, a parametric statistical test T-test with a level of significance of .05 was performed on the grades obtained by the students, finding that in the experimental group the average of students increased significantly as to those

who managed to pass the subject.

Table 4. Academic failure of the course

Group	% Academic failure	Final grade			
		Mean	Kurtosis	Variance test	t test
Control	21.62	3.36	2.99	.42	.000
Experimental	15.22	4.13	3.59		

4. DISCUSSION

The PBL strategy has a positive impact on educational indicators as markers of academic performance, it increases levels of motivation in students, facilitates the process and generates good results, despite the fact that classwork increases and it is more demanding. Consequently, it is considered feasible to implement on other courses at the university level, with the purpose of designing teaching-learning environments centered on students, where they can recognize how to generate significant learning.

The appropriate transversal integration of the project with the theoretical contents of the subject, not only strengthens the concepts discussed in class, but also allows to incorporate new concepts that did not belong to the course syllabus, enriching the theoretical base that students use to give a variety of creative answers to the presented problems, sustaining and arguing appropriately their ideas and consolidating a final paper that is written properly, showing a percentage increase in those skills associated to work autonomously, synthesize and write information, solve problems, propose, argue and execute ideas as compared to the control group. In this way, experimental group´ students are capable of appropriating the necessary knowledge to pass the course, presenting a slight increase in the average grade and a significant reduction in academic failure.

The results show that a weak point for the development of the activities as well as the completion of the project is the way in which the students conceive teamwork, within each group the students share the tasks and at the end of each activity they overlap the obtained results. This issue led to get a poor practice which not only minimizes the quality of the final product, but also limits the acquisition and development of all estimated skills within the project planning, for every single student.

Students conceived a poor notion of collaborative work due to they do not know how to manage time or plan their multiple academic activities optimally, which results in the claim to have a lot of small isolated results, which are juxtaposed at the end, seeking to get only a high result. this last part shows where the real issue lies, because it is not inaccurate to distribute tasks, what is poorly implemented is to try to superimpose the individual results of many tasks, without carrying out a process of feedback and consensus; where each member of the group understands what each individual result depicts as well as the achievement of the objectives as a team. When students succeed in implementing synergistic collaborative work strategies, they will be able to make better use of their time,

without sacrificing the acquisition and full development of their cognitive skills.

In the future, it is expected to be capable of implementing an analogous PBL process in the Chemistry subject, this process could improve academic performance of the students, as a consequence, the outcomes in the Biomaterials subject could improve because of having earlier experiences of collaborative work in projects. Likewise, it is necessary to look for new useful topics that allow projects to be developed, since the continuous repetition of the same project would exhaust the enthusiasm, affecting motivation in participants of this project.

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