

MATHEMATICS TEACHING AND LEARNING PROCESS: THE EFFECT OF PROBLEM-BASED LEARNING

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Abstract

This text is part of a larger study developed as part of the Final Internship Report for obtaining the master's degree in Teaching of the 1st Cycle of Basic Education and of Mathematics and Natural Sciences of the 2nd Cycle of Basic Education. Its theme is Problem-Based Learning (PBL), characterized as an innovative teaching and learning methodology, which translates into the multiplicity of materials, resources and strategies. It seems relevant to us to find activities that focus on the student to captivate his attention, thus putting him in the learning focus, essential in the current educational context.

In this paper we focus on the following question-problem: "How does PBL influence the teaching and learning process of mathematics?", considering the following objectives: i) to investigate whether PBL is favourable to the teaching-learning process of mathematics; ii) to reflect on mathematics educational practices based on PBL. The study, qualitative and interpretative, analyses two points of view: the students' view and perspectives on the educational practices experienced and the researcher/teacher's own self-reflection on their practices. The techniques used to collect data in investigation were participant observation and the survey through questionnaire applied to twenty-six students from the 4th grade of the elementary school.

The answers allowed us to collect very complete opinions, regarding the way to motivate students to the current educational reality, making them future adults with critical thinking, autonomy, argumentative capacity, self-determination and proactivity. The study shows that PBL proved to be a teaching and learning methodology that provides dynamism and student motivation. The results of the researcher's diary analysis, and the results of the questionnaires, showed the students' interest in the teaching practices, a greater initiative in participating in activities, and a greater commitment to the work done. The students considered themselves more active and communicative, and valued the learning of the contents worked on. However, we also found constraints in PBL, from the teachers' point of view, namely time management and activities preparation. We conclude that the researcher/teacher needs to make a prior and thorough study of the group with which he/she will work, about the content themes to be developed, to then design a feasible planning in the time available, but that the PBL provides greater student involvement.

Keywords: PBL, elementary education, mathematics.

1 INTRODUCTION

PBL is a teaching and learning methodology "that motivates students to learn through involvement in a real problem. Students receiving PBL training simultaneously develop both problem-solving strategies and disciplinary knowledge bases."(1). This methodology intends to put the student at the center of the process and contribute to his or her own learning, to give meaning to the knowledge of several scientific areas while developing skills and abilities. "Developing the problem-solving abilities of elementary school students has been recognized as an important educational objective". (2)

PBL assumes the student as an autonomous being, with a critical spirit, relating socially and able to intervene in his context. The implementation of PBL goes through several stages. Initially a scenario is presented with a problem-issue that should emerge from the student's own reality; the student researches and collects data, interprets it to develop and structure the problem, and then presents the evidence and/or doubts; in class, students discuss "results of their investigations and work together to formulate and evaluate possible solutions as they actively engage in learning" (3); - after the debate, new topics for further research may arise, so this process is cyclical.

In PBL, problems serve a “number of functions: trigger students’ motivation to study necessary content knowledge; problems afford the content knowledge to be studied; contextualize the content knowledge; and problems provide a workspace for students to apply the content knowledge. (5)

The multiplicity of resources and strategies is a very important aspect of PBL, since it must be dynamic, stimulating the main actor in the process and providing him with the necessary tools for his activities and research: the student. The teacher has the role of presenting the scenario and the problem-issue, questioning the students, answering their doubts whenever necessary, mediating their answers and debates, evaluating, and understanding the path that will have to advise them so that they acquire knowledge and find solutions. “PBL as a method and a philosophy can enrich learning and school experiences for both students and teachers.” (4) Thus, it is important for the teacher to be on the lookout for opportunities to apply PBL.

It is important to mention that the classroom and the school are spaces for socializing, learning, sharing knowledge and experiences, contributing to work among peers, in small groups and large groups, which is more stimulating. Furthermore, through PBL, content learning becomes meaningful because it is contextualized and applied, while students develop critical thinking, research, and communication skills.

In mathematics, the (in)effectiveness of learning may be related to the teaching and learning methodology used, the resources available, and the motivation of the students. Leading the student to give meaning to his learning, making connections and conjectures, through “problem-solving based active learning approach (...) enables students to view problems with a deeper perspective, thereby experiencing deeper learning, undertaking critical thinking and utilizing an analytic reasoning process”(6).

In fact, mathematics is often perceived by students as difficult or not very accessible. In classrooms there is often a major concern with the outcome rather than the process of solving a task. Mathematics students “therefore need to experience the process of research in mathematics themselves. In this sense, PBL may be a good tool as the teaching is bottom-up and explorative where the students are in unknown territory trying to find a way to reach some kind of conclusion to the issues they endeavour to investigate – and prove”. (7).

2 METHODOLOGY

The research conducted was qualitative, interpretative, and descriptive in nature. The sample included 26 4th grade students, of which 14 were female and 12 males. Five students had been diagnosed with learning difficulties and were monitored by a support teacher twice a week. Being a qualitative research we sought to obtain from the subjects to be investigated (...) information and understanding (the meaning) of certain behaviors, emotions, ways of being, being and thinking” (8). We used observation, one of the most used techniques in educational research because “some of the major strengths of using classroom observation allow educators to do the following: To permit researchers to study the processes of education in naturalistic setting, to provide more detailed and precise evidence than other data sources, to stimulate change and verify that the change occurred and to provide a coherent, well-substantiated knowledge base about effective instruction” (9). Participant observation, “can be a mutual gift between the observer and the observed where both gain in ‘self-awareness, perspective, an introduction to new techniques and fresh enthusiasm for their craft”. (10) Data were collected using participant observation field notes that focused on the teacher-researcher’s educational practices and the students’ attitudes and feelings before and during the PBL interventions, and a questionnaire survey.

The observation data later became the researcher’s diary. Journaling as a research tool is based on a regular, reflective account and description of past events, before, during, and after each situation. Thus, after the observation, the researcher departed from her field notes and devoted herself to writing and describing and reflecting. The researcher “records ideas, strategies, reflections, hunches” (11) and reports “what she hears, sees, experiences and thinks in the course of collecting and reflecting on the data “from a qualitative perspective”. Subsequently, these data were organized and resulted in a diary “Researcher’s Diary”.

The writing of a diary as a research instrument may seem easy, but it involves great complexity. The diary is seen as a tool that allows the teacher to investigate and reflect on educational practice (12). Taking into account, the phases of this study, the diary was also important from the point of view of the effectiveness of active learning methodologies, it allows, from a narrative, to verify the difficulties faced in the process of applying these methodologies (12). The analysis of the researcher’s diary aimed to carry out a self-reflection on the activities developed, on the practices involving PBL.

The questionnaire survey applied to students had two open-ended questions, to be able to detect students' perceptions, subjective experiences, and representations about their experience in PBL. The aim was to get a broader opinion, to extract as much information as possible for the study.

The content analysis of the researcher's diary and the questionnaire was supported by software. We used the MAXQDA software which allowed us to build a set of schemes that highlight the aspects included/referred to in the researcher's diary.

3 RESULTS

The main objective of the analysis of the researcher's diary and the answers to the questionnaires was to reflect on the PBL-based educational practices. After a careful and thorough reading, we selected the aspects most frequently mentioned by the researcher and the students and carried out a posteriori categorization using data triangulation. The categories considered were subject area - mathematics; learning process; task (resources, strategies, materials); motivation.

3.1 Study categories

Table 1. Teacher/researcher and student views on PBL.

Categories	Exemples	
	Students	Research Fellow/Teacher
Subject area - mathematics	"the classes (...) that I liked the most were the middle school and math because they had several challenges"; "fun and educational classes, especially math"; "I loved math because you made me learn".	"I had some difficulty preparing for this lesson"; "the students always show a lot of enthusiasm in math classes".
Learning Process	"going to the board to do math to get better"; "I was able to learn"; "how she explains to us calmly and patiently"; "sometimes I had some doubts, but she helped me and I liked that".	"They showed mastery of the knowledge"; "they had very original ideas, (...) they built on what they had learned"; "the students were all very attentive and engaged"
Task (resources, strategies, materials)	"it was the most fun class of all with powerpoints/challenges, maria songs, with cognomen riddles ("it helped a lot"); "we do a lot of activities and challenges" "the classes are creative, funny, fun."; "I loved the games we did with her".	"We approached the content using challenges"; referred to expressions such as: ("This is the coolest game I've ever played", "I want to play this more often", "please say another fraction"); "it was very interesting, the students showed the taste for group presentation."
Students motivation	"with very motivating and well taught classes"; "the classes are: creative, funny, entertaining"; "gave us wonderful classes, I loved the classes".	"the motivation given to the students ended up making the class very pleasant. I felt the students were challenged and pleased too"; "the students showed a lot of commitment to the task feeling challenged."

3.1.1 Subject area - mathematics

Mathematics was mentioned as the subject in which the students' interest was most notable and where the researcher found it easiest to use PBL. The researcher mentioned that "some students showed doubts in representing fractions on the number line, but after being called to the board, reflecting and explaining their reasoning to their classmates, they showed understanding." The students showed some insecurity, initially, but after reorganizing their reasoning, discussing with classmates and reflecting, they resolved these difficulties and acquired the intended knowledge as we can see in the following statement: "going to the board to do math to improve". In the final phase of the study, observations were recorded such as: "The students showed a lot of commitment to the task feeling challenged". The implementation of PBL in mathematics was considered by the researcher as the most relevant in her experiences. This was related to how easy or difficult it was to use PBL methodology in different subject areas. In mathematics, the researcher found it easier to construct different strategies and resources, although there were also limitations in the organization of the classes, since she did not master PBL, which has improved over time.

3.1.2 *Learning process*

With regard to learning outcomes, the answers were quite positive. Initially, it is mentioned that the students "had a lot of difficulty in the last task which was a problem involving logical reasoning. Autonomously, only 3 students managed to reach a solution, each one using a different process, which made the whole situation more interesting and rich"; then "all together, after the explanations of each student, they reached a conclusion, without ever mentioning whether it was correct, incorrect or incomplete", so that, through debate and reflection, the students built knowledge. As can be seen in table X, students mentioned: "I managed to learn"; "how calmly and patiently she explains"; "sometimes I had some doubts, but she helped me and I liked that". The students showed satisfaction in being able to autonomously demonstrate to their peers their reasoning, the connections, and the process they used.

The researcher found that the students: "showed that they mastered the knowledge"; "had very original ideas, (...) based on what they had learned"; "they were all very attentive and committed".

Although PBL values group work, there was some difficulty in managing time, noise and understanding whether everyone in the group was working towards the same goal. These aspects were influenced by little experience and the fact that the class was made up of many members. One of the students pointed out this scarcity of group work as a point to change in the teacher's teaching practice, arguing that "I could have done more group work, I love working in groups."

3.1.3 *Task (resources, strategies, materials)*

In the educational practice, the following emerged essentially: enrichment activities, trips to the board, brainstorming, dramatizations, videos, tokens, multimedia presentations, textbooks, songs, books, games, and problem situations. The diversity of tasks is in accordance with the assumptions of PBL, as mentioned earlier in this study. The students showed interest in this diversity, and many times, some activities were the motto for the following activities. The brainstorming was emphasized in a very positive way, as it contributed to the students' reflection and development of argumentation skills, and to the presentation of their ideas, resulting in a joint work. The trips to the board were the episodes with the highest number of references and allowed us to show how the explanations presented by a student allow him to consolidate ideas about the topic, but also contribute to the learning of classmates who might not be following the teacher's clarifications.

The challenges were the activities in which the researcher felt that students were fully involved and excited, not only because of the surprise factor, but also because of some competitiveness that could exist between pairs, regarding the search for answers and solutions, motivating them to develop communication and organize ideas to then argue and debate the result with their peers. The researcher pointed out: "I used the same strategy of asking several students, because it draws the attention of the more inattentive ones and makes the class more dynamic". The dramatizations were very positive, as the students-built knowledge and developed skills such as lexical ability (using new vocabulary), written and oral communication, posture, voice projection, and self-confidence.

The resources most mentioned by the researcher were multimedia presentations and games that contributed to an easier understanding of the contents by the students. Not only were they the most used, but also the ones that pleased everyone the most, because it was possible to observe the interest and involvement of the students, who referred to expressions like "this is the coolest game I've ever played" or "I want to play this more often. In fact, the textbooks, the worksheets, and the videos were the easiest resources to fit into the classes, since they were already prepared (except the worksheets), but they were the three resources in which the students showed the least interest and, as such, the ones that the researcher liked the least. The videos did not work as expected because, when they were used, the students were distracted and focused on irrelevant factors, such as the voices of the characters, and not on the thematic content itself.

The songs were highly valued by the students. From the researcher's perspective, it was a significant way to consolidate a content, because it excited the students and held their attention to the lyrics of those songs, which addressed a specific content.

Children's books generated a lot of enthusiasm; when we dramatized a story, students showed their emotions verbally and through facial expressions.

3.1.4 *Students' motivation*

In the more expository and verbalistic lessons, centered on the teacher's explanations, the students' boredom and lack of commitment were noted.

In group work, role plays and/or challenges, expressions of surprise were registered, showing that the students were involved in the activity and developed creativity, elaborating their ideas or opinions in a more complete manner. Autonomy was emphasized, since in certain works where the teacher did not present all the indications, the students manifested a critical sense, realizing that there were elements missing and tried to find solutions to their problems, more individually or with their classmates, in a first instance. This situation also evidenced the students' involvement in the activities. The students mentioned: "very motivating and well given classes"; "the classes are creative, funny, entertaining"; "he gave us wonderful classes, I loved the classes".

It was concluded that there was an advantage to giving the students some freedom to solve the problems by researching and looking for solutions.

4 CONCLUSIONS

In this study it was possible to realize that the teacher's lack of experience and training in the implementation of more innovative methodologies may affect the results. With his evolution, with his growth, the teacher will be able to better develop PBL, and better adapt to the work group, that is, the class with which he will work.

This teaching and learning methodology, PBL, is very positive from the point of view of student learning, both from the point of view of scientific knowledge and from the point of view of developing soft skills and, above all, their motivation. The whole PBL process becomes more promoter of creativity and allows the student to construct knowledge. In addition, it also develops critical thinking, the power of argumentation, the ability to work in groups and resilience, because the challenges require the student to interpret, try to solve them as many times as necessary, discuss the ideas with colleagues, until they reach a conclusion.

With strategies based on PBL, mathematics becomes more attractive to students, with a wide variety of resources, strategies, and materials. In this study, we chose to develop the tasks using games, multimedia resources, books, and brainstorming, making the teaching practices more diverse and creative, while maintaining the students' focus and attention.

For the teacher, this methodology is demanding, because it is necessary to plan the lesson thoroughly (and it was felt how difficult it is, sometimes, to define motivating problem situations...), prepare different resources and strategies and manage time to achieve the objectives respecting the official documents. But the advantages are worthwhile.

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