Effectiveness of problem-based learning in academic performance of course "Physics I"

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***Abstract*— These article shows efficiency of Problem-Based Learning (PBL) in academic performance of course "Physics I", specifically in how learning arises across experience. For this, existing methodologies were adapted in PBL in order to generate six methodological proposals, developed during an academic semester.**

Impact of PBL was evident at end of semester. It was validated through non-parametric test from Mac Nemar, with a confidence level of 95%. Conclusion is PBL turned out to be highly effective, especially at highest levels of academic performance (demanding application and analysis skills) in which there are found substantial differences with regard of group of control. On the other hand, in area of comprehension, such a difference was not noticed, which indicates that application of above-mentioned methodology (regarding this capability) is not interesting for teacher.

This investigation contributes with a program that relies on instruments that measure comprehension, application and analysis of beginning of classic physics in students of course "Physics I". Likewise, a guide of fieldwork provides with guidelines of employment for this course in top level, and examples for its later use.

Keywords—Problem-Based Learning, academic performance.

I. INTRODUCTION

Accelerated development of science and technology faces our students with a large volume of information, which makes its assimilation more and more complicated during teaching-learning process. That is why it is necessary for teachers to be better prepared for scientific teaching. This implies also for them to improve their pedagogical practice in aspects of knowledge, organization of learning outcomes, strategies and means, assessment and classroom climate. Teachers must consider that students face new challenges such as speed of change, complexity and interdisciplinary aspects, ethical and social dimensions, as well as civic issues [1] in which they actively participate, so that they can acquire knowledge and identify their deficiencies.

Defining real situations in which t concepts developed in classroom are put into practice often becomes complex for students, since conceptual application is minimal in context of profession [2]. Contents of course "Physics I" are not unfamiliar to this problem, therefore it was proposed to improve way of teaching this course through PBL, which allows learning from experience [3].

This method implies thinking about need of a change in way science is understood, taught and thought, to formulate and to develop tools and methods centered on students. This implies that students are able to find solutions to questions that will arise in their working environment; with critical thinking that develops skills and abilities to deal with diverse problems, above all, their investigative approach to developed concepts [4].

In our context, following question which is base of our investigation arises: How does application of PBL method improve academic achievement levels of students in first semester of "Physics I".

II. THEORETICAL BASES

PBL, according to Araujo and Sastre [5], is a method that favors development of skills, abilities and competencies demanded in labor world under a more effective and stimulating approach than traditional model. This active methodology integrates problems of real life and allows students to analyze, identify deficiencies in their own learning and investigate in a collaborative way to solve problems.

In PBL, activity revolves around discussion of a problem applied to future professional life, making it possible to learn from experience when working on a specific problem. It is a method that stimulates self-learning and student's practice, when confronting real situations and helps to identify deficiencies in their knowledge (see figure 1 from Morales and Landa, [6]).

Meaning of term "academic performance" corresponds to level of students' learning as a result of teaching-learning process. Explanation of this concept recognizes influence of factors of diverse nature. In field of education, Bloom's taxonomy has become a universal tool for assessing learning achievement; that's why it is the reason for using it in this research [7]. Academic performance is defined as achievement in terms of understanding, analysis and application [8].

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III. METHODOLOGY

In present study, PBL method was applied. We worked with categorical variables. Academic performance is defined as achievement in terms of understanding, analysis and application of some basic principles of physics in specific real situations considered. To measure impact of PBL in academic performance, it is discussed twice: before implementation and after it. Observation was made during pre-intervention, in sessions and subsequent intervention activities [9].

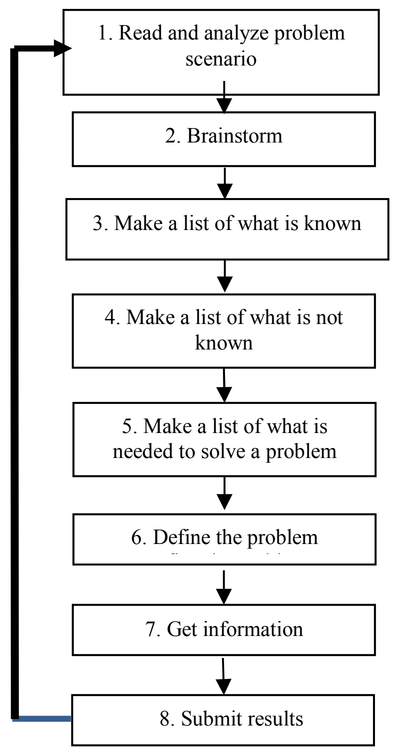

FIG. I. DEVELOPMENT OF PBL PROCESS. SOURCE: MORALES AND LANDA, 2004.

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Table I shows independent variable and dependent variable of study and its evaluation tools.

This research had an experimental design using a test (experimental) group and a control group. PBL (independent variable) was applied during a semester during course with modules elaborated and problems applied to professional program. Dependent variable was measured twice (before and after).

V. ASSESSMENT OF ACADEMIC PERFORMANCE

Instrument of educational evaluation, applied in input and output tests in order to measure academic performance, allowed us to estimate dependent variable. Two experts in teaching physics constructed this instrument. For content validation, we used a dichotomous matrix that was tested by eight teachers with an experience of more than ten years in teaching this subject. An arithmetic mean of 0.875 was obtained with a maximum standard deviation of 0.35. Validation was confirmed with convergence analysis of responses, giving a value of 95.83%. To validate construct, test was applied to students of course "Physics II", under assumption of being a group with competences to be measured, having already approved subject. However, sections were changed to avoid induction of responses. A Cronbach's alpha = 0.711 was obtained, resulting in an instrument with excellent reliability.

TABLE I. LIST OF TECHNIQUES ACCORDING TO VARIABLES

Variables	Techniques and instruments
Independent: Problem Based Learning (PBL)	• Six modules of laboratory according to plan of subjects of course "Physics I" • Six problems with application to program "Heavy Machinery Maintenance"
Dependent: Academic performance	Questionnaire and observation • Input test (Pre) • Output test (Pos) • Laboratory report • Plenary sessions • Results sheet

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VII. RESULTS

Input and output tests were applied to both groups (control and test) in order to compare results among them; for validation of hypothesis, Mc-Nemar statistical test was used. "Chi square" test was used for independent samples to compare differences between these groups.

In this research, we worked with selected topics of physics which are very important for program named "Heavy Equipment Maintenance".

Table 2 shows sequence of topics taught in course "Physics I" and articulated directly with aspects which are part of curriculum of professional program.

In all cases, model of Morales and Landa (eight phases) was applied:

Phase 1: Analysis of problem

Phase 2: Brainstorm

Phase 3: List of what is known: topics already acquired

Phase 4: List of what is not known: topics to be acquired

Phase 5: List of what is needed to solve a problem

Phase 6: Define problem

Phase 7: Collecting and processing information

Phase 8: Present results

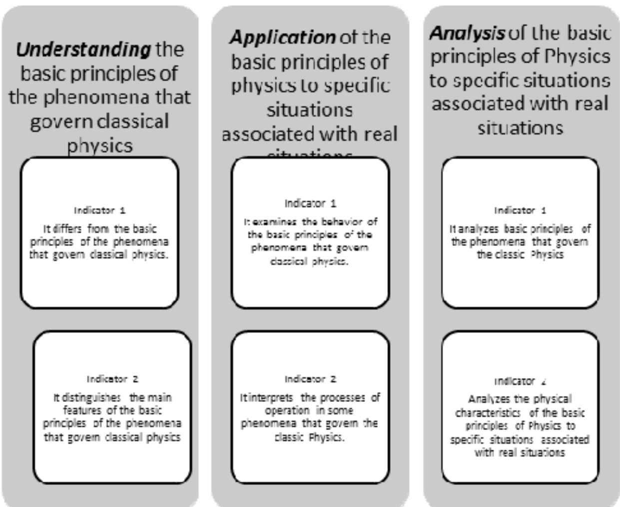

FIGURE II ORGANIZATION OF QUESTIONS ACCORDING TO DIMENSIONS TO BE EVALUATED.

Note: Structure of evaluation items of academic performance variable is shown. We have capability to "Understand" A1 and A2 indicators, capability "Application" for B1 and B2 indicators, capability "Analysis" for C1 and C2 indicators, for principles governing classical physics.

VIII. INTERPRETATION

Regarding results of test applied to measure three capabilities (input test), corresponding to baseline, mean value in each item analyzed is between 0 and 0.2, which would indicate a tendency towards zero. In addition, high standard deviation does not allow to establish a characteristic bias by group, but rather to assume heterogeneity in both groups. Observing variability in each of indicators by each capability, we obtain that in

Experimental group there are variations regarding collection of answers; indicator with greater variability is A1, that is to say, it is most heterogeneous. In case of control group there is no variability, i.e. responses are homogeneous over applied test.

After intervention, we will explain variations found in both test and control groups (we use bar graphs for each indicator) to analyze impact of PBL in course "Physics I", i.e. evaluation of both tests (named pre and post in figures) and their differences.

TABLE II. LIST OF TOPICS TAUGHT IN COURSE "PHYSICS I"

SESSION	ISSUE	TOPIC
1	Miscellaneous Air Relief in a C13 Engine	Thermodynamics, thermometry
2	Admission Valve Spring Break	Simple harmonic motion
3	Wear Pines in Frame of a Truck Hopper	Harmonic motion: waves
4	Tractor and Excavator Bearing Train Wear Measurement	Sound
5	Efficiency of Operators using Kontrax (Komatsu) or Caes (CAT)	Light
6	Efficiency of Operators using Accugrade Laser 2D	Optics

Results obtained in application of tests, are shown as follows.

TABLE III. TABLE 3: RESULTS OBTAINED IN INPUT TEST

		Group	Half	Typical deviation	Coefficient of variability
A. Understanding	Indicator A.1	Control	0.067	0.25	0.26
		Proof	0.21	0.41	0.51
	Indicator A.2	Control	0	0	0.00
		Proof	0.11	0.31	0.34
B. Application	Indicator B.1	Control	0	0	0.00
		Proof	0.05	0.23	0.23
	Indicator B.2	Control	0	0	0.00
		Proof	0.11	0.31	0.34
C. Analysis	Indicator C.1	Control	0	0	0.00
		Proof	0.05	0.23	0.23
	Indicator C.2	Control	0	0	0.00
		Proof	0.11	0.31	0.34

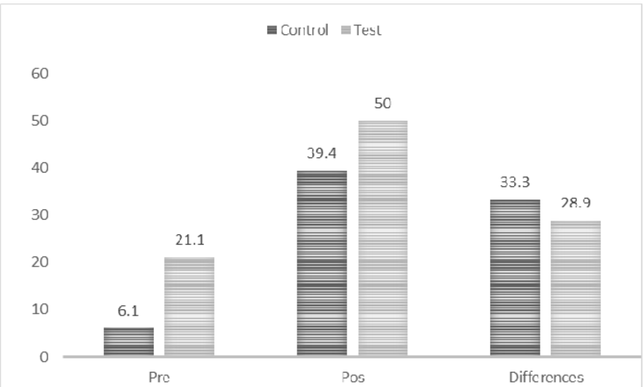

FIG. III. INDICATOR A.1 FOR "UNDERSTANDING" DIMENSION .

Description: referring to A.1 indicator, results are arranged in percentages for determining contrasts of increases. We observe that in control group, there was a significant increase of 33.3% in difference element of basic principles governing phenomena of classical physics. Likewise, test group, which starts from higher levels (21.1%), experiences a slightly lower increase, of 28.9%. Thus, there are no differences regarding methodological task of teacher.

Description: distinguishes main features of basic principles governing phenomena of classical physics; A.2 indicator shows that differences in results of control group and test one (0% versus 10.5%, respectively). These are greater than for indicator A.1. Both groups increased their percentages to 39.5% (control) and 52.6% (test), in output test, with increase being greater in test group.

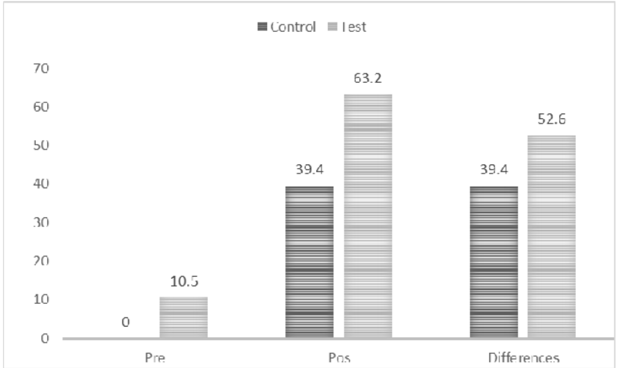

FIG. IV. INDICATOR A.2 FOR "UNDERSTANDING" DIMENSION

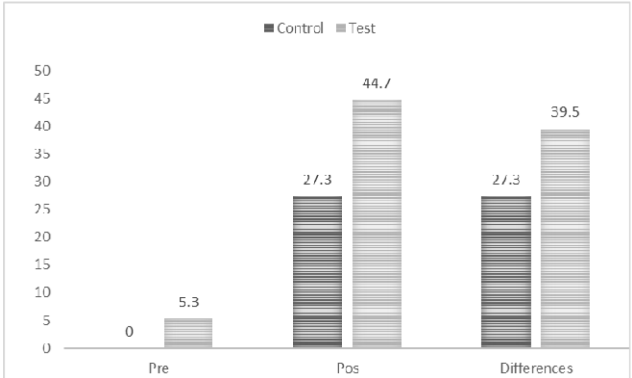

FIG. V. INDICATOR B.1 FOR "APPLICATION" DIMENSION

Description: regarding indicator B.1, there is an increase of 27.3% in control group compared to an increase of 39.5% in test group, which means a difference of 12.2% in favor of intervened group.

Description: differences of some phenomena that govern classical physics based on B.2 indicator; differences between control and test groups are much higher than in case of previous indicator (0% and 10.5%, respectively). In output test, increase is more important in test group (52.6%) than in control group (30.3%).

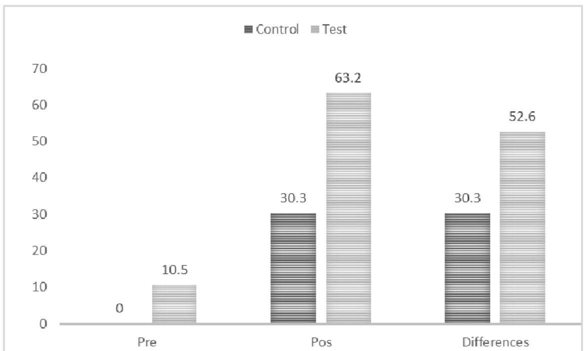

FIGURE VI. INDICATOR B.2 FOR "APPLICATION" DIMENSION

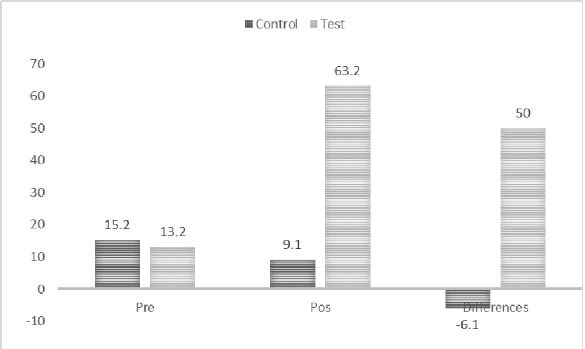

FIGURE VII. INDICATOR C.1 FOR “ANALYSIS” DIMENSION.

Description: in C.1 indicator, we observed a decrease in control group (-6.1%) between input and output tests, while test group experienced an increase of 50%. This would imply that only student in intervention group is able to analyze basic principles of phenomena that govern classical physics.

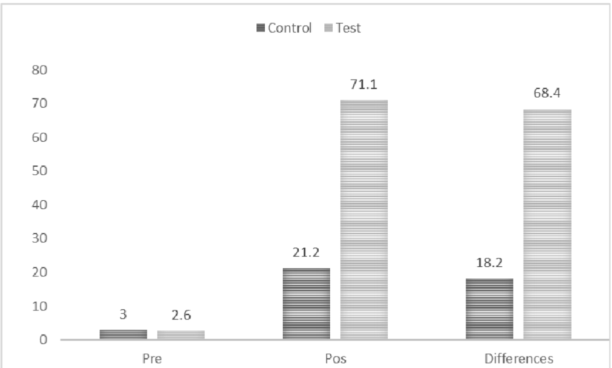

FIGURE VIII. INDICATOR C.2 OF ANALYSIS DIMENSION.

Description: finally, for physical characteristic descriptor “Analysis”, basic principles of physics to specific situations associated with real situations, corresponding to indicator C.2, both groups start with results of about 3% and increase to 21%, 2% in control group and a strong 71.1% in test group. There is also a difference of 50.2% between tests´ results increments for control and test groups.

IX. DISCUSSION

A. CAPABILITY UNDERSTANDING:

It has already been mentioned that for this item corresponds analysis of indicators A1 and A2. Both groups achieved increases in both tests, 39.5% in control group versus 52.6% in test group, with latter being greater. These results would show that PBL approach influences academic performance, as Chen & Hu [10] recognizes, in contrast to classical lecturing.

Students of course “Physics I” are able to distinguish main features of basic principles of phenomena that govern classical physics. This would imply that it is possible to use PBL as a teaching strategy not only in this course but also in Mathematics, as pointed out in study by Abdullah and Tarmizi [11] , which shows that PBL not only improves problem solving skills, but also teamwork and communication skills.

According to results, we can say that hypothesis, *"application of problem - based learning improves understanding of basic principles of phenomena governing classical physics"*, is not fully confirmed, so statement is not definitional. However, it might be useful but not decisive to acquire such capability and to develop reasoning, communication and decision-making, as mentioned by Pezoa & Labra [12].

B. CAPABILITY APPLICATION

For indicators B1 and B2 it was obtained 39.5% and 52.6% confirming work of Nuñez & Gonzales [13], i.e. capability “Application” is more significant in test group than in control group and it is concluded that PBL is most useful in conceptual development than traditional, which was applied in control group. Results obtained by Abdullah, Tarmizi y Abu [14] on students' perception of being better prepared for practical activities provided by PBL method by increasing their safety, as a side effect.

C. CAPABILITY ANALYSIS

Hypothesis *"application of problem - based learning improves analysis of basic principles governing phenomena of classical physics"* is verified according to results presented (input vs. output tests’ increases of 50% and 68.4% in indicators C.1 and C.2 in test group).

Also, in article *"Problem - based learning: an alternative to traditional method"* (Campos, [15]) it is reported that student recognizes advantages of PBL method, since it helps increase their ability for self - learning and ability of critical analysis of information acquired.

Study of Millan & Semer [16] also verifies these results, corroborating a deep learning approach in relation to academic achievement in a course based on PBL; But not with application of other methods.

X. CONCLUSIONS

With regard to general aim, method named Problems Based Learning is effective in levels of academic performance of students of first semester in course “Physics I” (it proves not parametric Mc Nemar to 95 % of confidence), especially in highest levels of academic performance, in which dimensions of application and analysis are important.

Although use of PBL contributes to understanding of basic principles of phenomena that rule classical physics in students of course “Physics I”, it must be mentioned that other methods used in a regular course do same.

In case of application of basic principles of phenomena that regulate classical physics in students of course “Physics I”, impact of PBL is greater than using a traditional method.

PBL contributes very effectively to complexity of students' thinking skills, such as analyzing basic principles of phenomena that rule classical physics.

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