A study on the relevance of laboratory practice and peer instruction in physics education

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Abstract

A teaching-learning methodology is presented through the implementation of two team teaching techniques simultaneously: peer instruction (PI) and home laboratory practices in Physics. The research was quantitative in nature, so the stages corresponding to this type of study were followed. The development of the technique was studied in two independent groups of students, one corresponding to the control group (CG, 33 students), and the other to the experimental group (EG, 31 students). The method showed a significant progress in the learning of the Physics subject in the EG compared to the control group. The progress reached an improvement of approximately 15% in the CG when the PI technique was performed, and an increase of up to 23.2% when the laboratory practices were implemented at home, in particular the laboratory experiences were performed with everyday materials.

Key words: Instruction, peers, laboratory, team, collaborative.

Introduction

Currently, the new challenges of education make it necessary that the training of students at all levels be strengthened with scientific knowledge, in such a way that it gives each individual a critical view of the world from a research point of view (Ladino & Fonseca, 2010). For Revelo (2014), at this instant, scientific knowledge is developed due to the work done between synergies and research groups around the world. Thus, in the knowledge society, collaborative work between different teams at any level is essential. In recent years, different strategies have emerged to approach science through collaborative learning. One of these strategies is known as Peer Instruction (PI), adapted in 1991 by Professor Eric Mazur of Harvard University (Pinargote, 2014). In the words of (Revelo, 2014), Mazur concludes that, through the dialog between peers, taking advantage of their similarities and empathy, knowledge can be shared.

Since 1991, Eric Mazur has been dedicated to disseminating the PI method, which has been widely known in Anglo-Saxon countries; in Latin America and Eastern countries, it is just an idea in current pedagogy (Revelo, 2014). In Colombia, Escudero (2014) put the PI method into practice in the learning of basic mathematics in two groups of students of Basic Sciences at Universidad del Norte in Barranquilla. He implemented a mixed research design. He applied a before and after test to determine the impact of the method. In addition, he conducted surveys with Likert-type questionnaires to investigate the learners' favorable and unfavorable perceptions of the method with the support of immediate response cards "clickers".

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Escudero (2014), points out that, in terms of student performance, positive results were found, with a percentage of approval of 88% in one of the courses and 91% in the other. Both groups evidenced favorable perception regarding the implementation of the method, with a percentage of favorability above 80% in each of the items evaluated. Likewise, Escudero (2014) highlights the positive impact of the PI method according to the results presented both quantitatively and qualitatively, which helped establish a great empathy between the students and the teacher.

The evidence reported in (Salinas, 2013) states that subjects such as Physics are often tedious to learn by students, as well as complicated to teach by teachers, due to the complexity of some phenomena that are often difficult to analyze given the abstract ideas underlying the problem. One of the didactic tools that has always been part of the teaching-learning process in science, and that helps to mediate the difficulty in understanding the phenomenon, is the linking of laboratory practices or experiences as support for the analysis or theoretical developments shared in the classroom (Carrascosa et al., 2006). Currently, some teachers have complemented these laboratory experiences with other tools such as the use of virtual learning environments, software, simulations and remote or virtual laboratories. Such is the case of Rodríguez and Llovera (2014) who, from the use of physical and virtual laboratories, determined an increase in significant student learning through the complementary use of the two techniques.

For Hodson (1994), the implementation of laboratory work in science teaching involves objectives such as motivating students to learn science, teaching laboratory techniques, giving depth to scientific knowledge, instructing students about the scientific method and its implementation, and developing scientific attitudes such as inquiry and the generation of new ideas. In the same way, Salinas and Colombo (1996) state that experimental activities constitute a primordial element within the process of knowledge construction, as long as they are directly related to problem solving and the concepts that the student has about the subject of study. In the same sense, Martínez, Cobos and Torres (2015) confirm that the teaching-learning process is more enriching if the experimental activities of application lead to modeling previously mathematized situations.

For Gil and Valdés (1996), experimental practices allow to further study the theory and prior knowledge that the student has about the subject. They involve the student in the identification of scientific work, allow for collaborative teamwork and positive interaction between students and teachers, motivate the student, which increases interest in the work, foster creativity and allow students and teachers to reflect on the process. Carrascosa, Gil and Vilches (2006) developed several investigations on the importance and relevance of experimental practices in Physics classes, managing to conclude that "they develop curiosity, arouse discussions, demand reflection, elaboration of hypotheses and critical spirit, teach to analyze the results and express them correctly, as well as favor a better perception of the relationship between science and technology" (p.159). Recently Castillo (2019), presented a teaching-learning strategy oriented to favor 11th-grade students. In it, pre-test and post-test tests were conducted with two groups, one control and one experimental. The efficacy of the method was proved according to the data analyzed. It is important to highlight that, as Quiceno, Barreneche and Pinto (2017) state, the application of collaborative work strategies, such as the PI, also contributes to the development of communication or leadership skills.

This paper is distributed as follows. In section 2, the strategy implemented in the research is presented: PI and inclusion of laboratory practices. In addition, the way in which the data were analyzed and presented is shown. Section 3 is dedicated to the analysis of the results. The characteristics of the sample and the results obtained in the intervention tests are reviewed. Section 4 presents the conclusions of the intervention through the implementation of the teaching and learning strategy used.

Methodology

Over the years there is a belief that Physics is a complex subject to teach and with reduced learning by the apprentices (Muñoz, 2015). For Zules (2013), it is essential to find a strategy in which the student understands the importance of Physics as a means to understand their environment, which is basic between their educational and occupational training, since the conflict that a student may have to describe natural phenomena can keep them away from job opportunities. Likewise, as stated by Charro, Gómez and Plaza (2013), there is a need to promote scientific literacy and open science as a human activity of great social relevance.

Thus, experimental work in science education has been a topic of discussion for years. For example, Flórez (2011) planned the development of laboratory experiences of movements in two dimensions using nature as a source of experiences obtaining a significant advance in the teaching of Physics in the tenth grade.

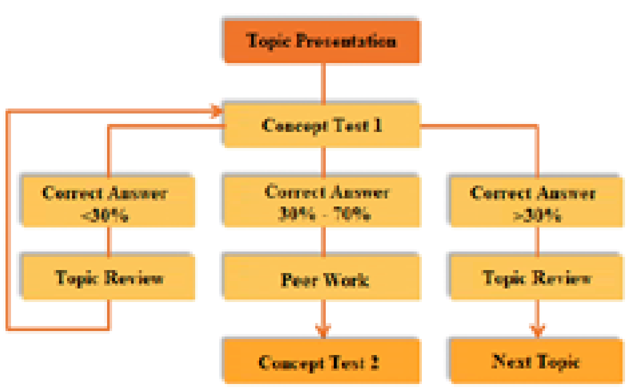
In this research, a home lab practice related to the well-known Hooke's Law was specifically implemented. For the development of the practice, the trainees were asked to perform the experience using everyday materials such as an elastic rope, objects of different masses and a tape measure or flexometer. After carrying out the practice, the students had to submit a report related to the lab experience. Previously, the teacher oriented and explained the experience by means of a methodological guide or laboratory guide.

The procedure for the development of the practice was previously presented by the teacher through a methodological guide, that is, the report presented by the students was based on a laboratory guide and report format handed-in, explained and guided by the teacher.

For the application of the PI method, students attended the class or session, having previously done some reading about the topics to be addressed. The teacher made a series of short explanations about the key aspects of the subject. Each illustration by the teacher was accompanied by a conceptual test, which was initially developed individually, then groups of students were organized with different answers. The task of each student is to persuade his or her peer with arguments that his or her answer is correct. Particularly in this stage, the teacher made interventions in the groups with the purpose of making clarifications without intervening in the decisions of the trainees. Subsequently, a new evaluation of the topic was carried out. If 70% of the class got the correct answer, the teacher explained it and continued with the next topic (Mazur, 2010; 1997).

A representative schematic of the PI method is shown in Figure 1.

Figure 1. *Flowchart of the Peer Instruction Method*



Source: Own elaboration

After the application of the strategy, the quantitative analysis of the data obtained and the elements collected, it was possible to solve the research question: How, from the realization of a lab experiences and using the method of peer instruction, can be induced in the student elements of motivation and interest in order to stimulate critical thinking that allows them to interpret the relationship between the variables of the problem in the subject of Physics?

The answer to the research question, considering a normal distribution, gave way to the project's Null Hypothesis or Ho, and its corresponding research hypothesis or H1. These were:

> Ho: *The methodology of lab practices and peer instruction in Physics teaching does not benefit Physics learning.*
>
> H1: *The methodology of lab practices and peer instruction in Physics teaching benefits Physics learning.*

The tests performed to test the rejection of the null hypothesis were the well-known Shapiro Wilk test, and the Mann Whitney test. The data from the pre-test and post-test were presented and analyzed using the measures of central tendency, such as mean, median, mode and variance. The test applied for hypothesis testing was significance level. If the significance value is smaller than the expected significance level, the result is considered statistically significant. The significance level for the present study was 0.05, which implies that there is a 95% probability of not being wrong about the method. In other words, a statistically significant result has less than a 5% chance of occurring by chance (Hernández, Fernández, & Bapista, 2014). All data were analyzed through the use of Wolfram Mathematica 12.1 software.

Results

This section presents the results of the research after the intervention was carried out. The analysis of the results allowed us to solve the question associated with the problem statement. The analysis of the data was based on Hernández, Fernández and Baptista (2014). The section is distributed as follows: initially the characteristics of the sample population

Capilla de Santa Bárbara - Floridablanca (Santander) are presented, then the results of the initial and final tests are analyzed. Finally, the results of the CG and EG groups are compared, and the influence of the lab practices on the final results of the trainees' academic performance is also reviewed.

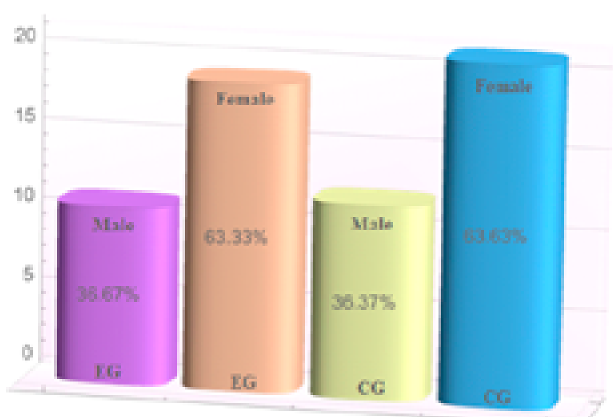
There was a sample of 63 students, of which 63.49% were female and 36.51% were male. Therefore, it is feasible to state that the population is heterogeneous in terms of gender. Likewise, although there are fewer males than females, the numbers are equivalent in both the control and experimental groups (Table 1 and Figure 2).

Table 1. *Characterization by gender of the sample*

Study sample	Female	Percentage (%)	Male	Percentage (%)	N° of students
Experimental group	19	63.33	11	36.67	30
Control group	21	63.63	12	36.37	33

Source: Own elaboration

Figure 2. *Characterization by gender of the sample.*



Source: Own elaboration with Wolfram Mathematica from the results obtained.

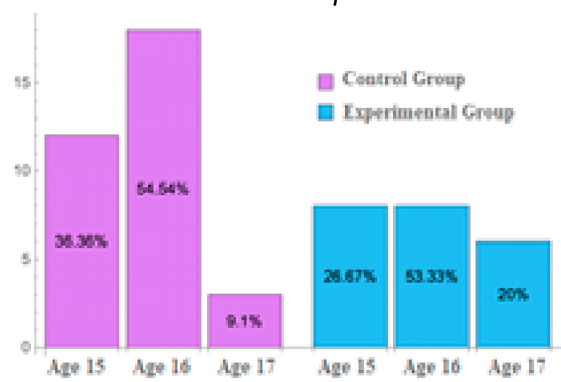
On the other hand, in terms of age, the students are between 15 and 17 years old, finding that most of the students are between 15 and 16 years old, the age characteristics of each of the groups are analogous (Table 2 and Figure 3).

Table 2. *Characterization by age of the sample*

Age	Control group (# of students)	Percentage (%)	Experimental group (# of students)	Percentage (%)
15	12	36.36	8	26.67
16	18	54.54	16	53.33
17	3	9.1	6	20

Source: Own elaboration

Figure 3. *Characterization by age of the sample*



Source: Own elaboration with Wolfram Mathematica based on results obtained.

Tables 3 and 4 show the data for each group by level according to the peer instruction method for the pre-test and post-test and differentiated by group. The topics were taught as follows: pre-test and post-test 1 (Introduction to Dynamics); pre-test and post-test 2 (Types of forces); pre-test and post-test 3 (Newton's Laws). In the three subjects, situations were posed and solved, as well as Dynamics problems.

Table 3. *Number of students by performance level on Pre-tests 1–3*

Theme	Approval Ranks	Control group (# of students)	Experimental group (# of students)
Pre-test 1	0-70 %	28	25
	>70%	5	5
Pre-test 2	0-70 %	26	24
	>70%	7	6
Pre-test 3	0-70 %	30	22
	>70%	3	8

Source: Own elaboration

Table 4. *Number of students by performance level on Post-tests 1–3*

Theme	Approval Ranks	Control group (# of students)	Experimental group (# of students)
Post-test 1	0-70 %	17	11
	>70%	16	19
Posttest 2	0-70 %	18	8
	>70%	15	22
Post-test 3	0-70 %	16	5
	>70%	17	25

Source: Own elaboration

Tables 5 and 6 show a descriptive analysis of the measures of central tendency of the sample obtained, such as mean, median, mode, standard deviation for each group, as well as the composition of each sample in terms of percentages of students according to performance level.

Table 5. *Measures of central tendency of the pre-test*

Group–Test	Mean	Median	Mode	Variance	Standard Deviation
GE Pretest 1	49.63	54	21	460.72	21.46
GE Pretest 2	51.90	57	31	441.33	21.00
GE Pretest 3	53.77	57	57	451.22	21.24
GC Pretest 1	48.33	45	19	490.33	24.46
GC Pretest 2	50.24	55	25	461.67	22.00
GC Pretest 3	52.33	55	40	472.24	24.24

Source: Own elaboration from results obtained with Wolfram Mathematica.

Table 6. *Measures of central tendency of the post-test*

Group–Test	Mean	Median	Mode	Variance	Standard Deviation
GE post-test 1	73.87	70	95	316.65	21.46
GE post-test 2	76.74	79	86 y 100	298.47	21.46
GE post-test 3	80.68	85	100	278.56	21.14
GC post-test 1	65.33	65	75	380.33	22.00
GC post-test 2	68.24	70	76	312.24	24.24
GC post-test 3	65.33	74	76 y 80	322.33	21.42

Source: Own elaboration from results obtained with Wolfram Mathematica.

In Table 7 and 8, we can observe the p-value, which is less than alpha (0.05), then the null hypothesis is rejected, also it is inferred that the ordinal data analyzed are not normally distributed. Remember that, the Shapiro-Wilk test is used, because the sample size for each group is less than 50 students, also the p-value of the values or data show that we can have 95% certainty of doing the research correctly.

Table 7. *Pre-test normality test*

	Groups	Shapiro-Wilk Introduction to Dynamics		
		Statistic	GL	P-value
	Control (N=30)	0.921	30	0.029
	Experimental (N=33)	0,610	33	0,02
	Groups	**Shapiro-Wilk Types of Forces**		
		Statistic	GL	P-value
	Control (N=30)	0.930	30	0.049
Performance Level	Experimental (N=33)	0,680	33	0.03
	Groups	**Shapiro-Wilk Newton's Laws**		
		Statistic	GL	P-value
	Control (N=30)	0.922	30	0.031
	Experimental (N=33)	0.960	33	0.04
	Groups	**Shapiro-Wilk Total pre-test**		
		Statistic	GL	P-value
	Control (N=30)	0.922	90	0.00004
	Experimental (N=33)	0,752	96	0.001

Source: Own elaboration with Wolfram Mathematica from results obtained.

Table 8. *Post-test normality test*

Groups	Shapiro-Wilk Introduction to Dynamics		
	Statistic	GL	P-value
Control (N=30)	0.924	30	0.03
Experimental (N=33)	0.830	33	0.03
Groups	**Shapiro-Wilk Types of Forces**		
	Statistic	GL	P-value
Control (N=30)	0.917	30	0.019
Experimental (N=33)	0.890	33	0.020
Groups	**Shapiro-Wilk Newton's LawS**		
	Statistic	GL	P-value
Control (N=30)	0.854	30	0.0006
Experimental (N=33)	0.690	33	0.045
Groups	**Shapiro-Wilk Total pre-test**		
	Statistic	GL	P-value
Control (N=30)	0.897	90	2.15162*
Experimental (N=33)	0,572	96	0,002

Source: Own elaboration from results obtained with Wolfram Mathematica.

In Table 9 and 10, all p-value values are below 0.05 (α), so we discard the null hypothesis (Ho). The significance value $p<0.05$, is met in all intervention pathways; therefore, significant differences in the results are seen.

Table 9. *Mann-Whitney test pretest and post-test control group*

Topic	P-value
Introduction to Dynamics	$1.951*10^{-5}$
Types of force	10^{-5}
Newton's Laws	$1.607*10^{-6}$
Total	$6.846*10^{-15}$

Source: Own elaboration from results obtained in Wolfram Mathematica.

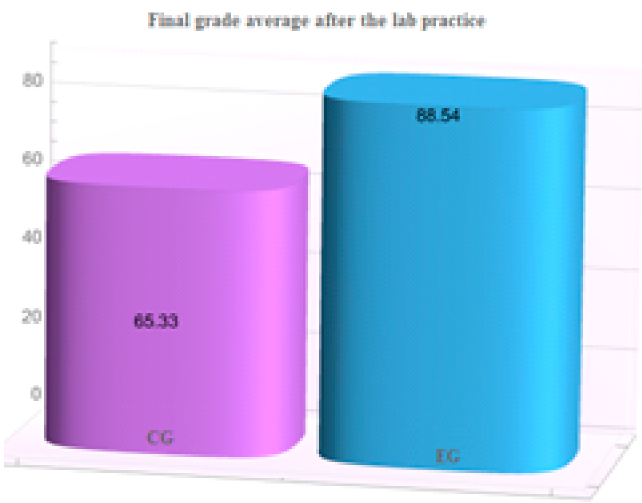
Table 10. *Mann-Whitney test for pre-test and post-test experimental group*

Topic	P-value
Introduction to Dynamics	$1.951*5$
Types of force	10^{-5}
Newton's Laws	$1.607*10^{-6}$
Total	$6.846*10^{-15}$

Source: Own elaboration from results obtained in Wolfram Mathematica.

To culminate the data analysis, in Fig. 4, the difference between the final scores of the control and experimental groups can be observed. The average reaches a contrast of approximately 23 points between the two groups. It is concluded that the implemented method of peer instruction and home laboratory favors the improvement of Physics teaching in the tenth grade.

Figure 4. *Mean for the CG and EG groups after the lab practice was performed.*

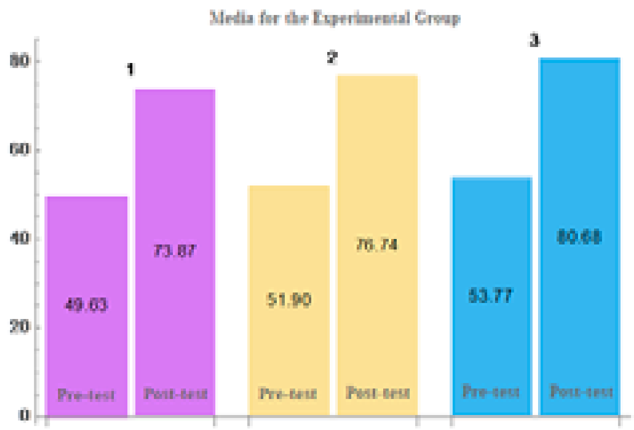


Source: Own elaboration with Wolfram Mathematica using data obtained.

Conclusions

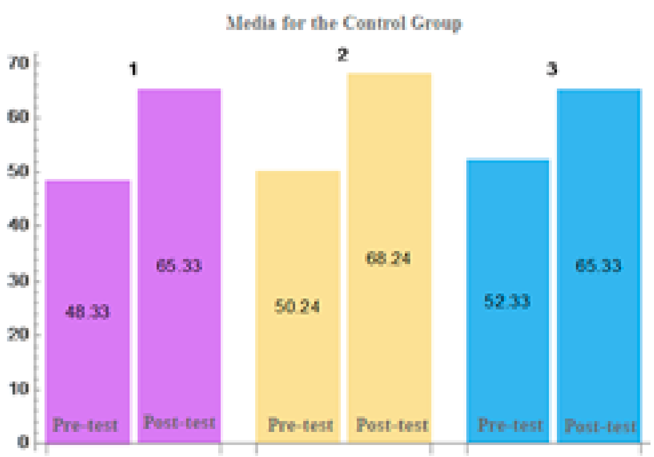
WHowever, the analysis of the data regarding the measures of central tendency of the pre-test 1-3 (Table 5), shows that more than 50% of the students are below the average, since the value of the median exceeds the value of the arithmetic average of the students' results. In the case of the post-test, see Table 6, a significant increase can be seen in the results with regard to the pre-test in the methodologies implemented for the two groups, CG with traditional methodology, and EG with PI method (see Figures 5 and 6). However, the percentage increase in the results of the final test by the EG stands out, as well as the most common score or mode of the EG, which was 100 in two of the three post-tests. Additionally, it can be concluded from Figures 5 and 6 that there was progress between the pre-test and post-test of the EG and CG.

Figure 5. *Mean for EG in pre-test and post-test.*



Source: Own elaboration with Wolfram Mathematica from results obtained.

Figure 6. *Mean for the CG in pre-test and post-test.*



Source: Own elaboration with Wolfram Mathematica using the results obtained.

On the other hand, the effectiveness of the methodology was tested by means of the Shapiro-Wilk test and Mann-Whitney test. In the two verifications a p-value below 0.05 was found (see Tables 8 to 10), which implies that the null hypothesis is rejected because of the probability of 95% of success in the methodology implemented in this research: the PI method and the home laboratory. Let us remember that, the significance value $p<0.05$, means that it is fulfilled in all the ways of the intervention; therefore, significant differences in the results are seen.

Finally, based on the results obtained, it can be concluded that, although the traditional methodology of the lecture class, in general, presented favorable results; the methodology implemented by the PI method and the home laboratory practice was more affective in favoring the learning of Physics. Consequently, the PI method and the laboratory at home accelerates the construction and management of knowledge, motivates meaningful learning, promotes collaborative learning and encourages hypotheses, observation and argumentative formulation due to the laboratory practices.

We consider that the results obtained and the classroom experiences lived with the students, lead us to propose a next stage of the research in which the tool can be extrapolated to other areas of physics such as fluids, thermodynamics, wave events and electromagnetism. In this way, we could leave evidence about the scope of the strategy in all areas of Physics.

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