Peer Instruction as a methodology to address the alternative conceptions in problem solving Einstein's special relativity

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Abstract

This paper focuses on the employment of the peer instruction methodology to address the alternative conceptions presented on the topic of Einstein's special relativity. An investigation is performed to expose the importance of this topic as typical approaches employed by many institutions around the globe do not generate the desired results. The alternative conceptions are exposed as a problem that must be overcome. This proposal is employed in order to improve the teaching-learning process in the resolution of problems of special relativity.

Keywords: Alternative Conceptions, Peer Instruction, Einstein's special relativity.

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I. INTRODUCTION

The Einstein's special relativity (ESR) issue has caused controversy as to whether it should be included or not in secondary schools. Arriassecq and Greca state: "...the Special Theory of Relativity (STR) is an important issue and should be incorporated into the curricula of Physics polimodal cycle, however it appears that lack a deep understanding of the relevant concepts to correctly interpret the STR and its implications, despite having received formal instruction in the subject ... " [3]. This result agrees with the one obtained by Pérez and Solbes [11].

If the ESR theory is hard to understand and solving problems of special relativity Einstein theme turns out to be even more complicated. This is due the application of concepts and sometimes these concepts are "distorted" by the students, because they already read or watched a video or just listen to talk about the issue and given the complexity of the topic they caught a misconception that Vergnaud calls an alternative conception [13].

There are different teaching methodologies, and one of the most current and used nowadays in American universities is the Peer Instruction.

The present study is aimed to researchers in education and physics teachers. The research topic is based on the Peer Instruction to address alternative conceptions of students and at the same time give an improvement in the teaching-learning process on the subject of ESR.

II. BACKGROUND

Throughout history man has faced deep changes and even more so when it comes to science. In the mid-nineteenth century, it was thought that Physics was booming and that anything was possible to be explained by using Newton's laws. However, a single experiment would shatter the known laws and thus the beginning of a new era for Physics, where grand scientists revolutionized the world with their theories such as Lorentz, Einstein and others.

In the last decade, academic institutions have begun to adopt a curriculum where topics of Modern Physics were involved. This has brought to light a concern when it comes to the understanding the issue of special relativity of Einstein. Alvarez highlights that knowledge of key concepts and the domain of Mathematics and Physics is essential for learning [2].

Students of an Ecuadorian high school that are registered in a course of Modern Physics, have difficulties when solving problems that require the application of spatial projection and the mathematical expression of a physical property (domain of Mathematics), presented in the unity of special relativity Einstein (domain of Physics). This issue extends towards other institutions in other countries, as indicated by Alemañ and Pérez [1]. In addition, Gagne mentions that problem solving is the intellectual ability to the highest level [4] and Vergnaud indicates that this is due

to the concepts in action and theorems in action turn out to be incorrect [2, 13].

Gilar states: "Within the theory of learning have several intellectual abilities, but particularly problem solving is the intellectual ability to the highest level." [5]. This leads us to reconsider, because teachers must keep in mind that action concepts and theorems of action affect problem solving and is part of the teacher's task to determine them and have schemes to promote change.

On the other hand; the Department of Physics of Harvard University, presents data to work for ten years employing the Peer Instruction method in courses of Calculus and Introductory Physics for undergraduate students, which has achieved positive results as the student manages to have a strength in conceptual reasoning and problem solving, these data was published by Crouch and Mazur [7].

Given the above, it can be said that problem solving is the hardest part to achieve in the learning process and it is essential to eliminate the alternative conceptions, but this requires adequate methodology and presents peer instruction as solution to this problem focuses on solving problems in the field of special relativity of Einstein.

III. PEER INSTRUCTION (PI)

PI is an instructional method in which students study in groups of two or three rather than alone. Instead of presenting the detailed analysis covered in the text book or lecture notes, it consists of a number of brief presentations on key points [8]. There is a wealth of evidence that peer learning and teaching is extremely effective for a wide range of goals, content, and students of different levels and personalities [9].

Mazur stated numerous advantages of PI. "(1) Discussions to convince your neighbors break the unavoidable monotony of passive lecturing; (2) The students do not merely assimilate the material presented to them; (3) Students think for themselves and put their thought into words" [10].

Crouch and Mazur reported data from ten years of teaching with PI in the calculus and algebra-based introductory physics courses for non-majors [10]. Their results indicated that students' mastery of both, conceptual reasoning and quantitative problem solving, inprove by implementing PI. They also found that 155 students taught with PI in spring 2000 showed better performance than 178 students taught traditionally, averaging 7.4 out of 10 compared to 5.5 out of 10, respectively [6].

Mazur have used Force Concept Inventory (FCI) and Mechanics Baseline Test (MBT) to assess his students' learning. The results showed the dramatic gain in student performance obtained on the FCI when he first used PI in 1991 [10]. This gain was reproduced in subsequent years. In the posttest, the scores strongly shifted towards full marks and only 4 % of the students remained below the cut off point for the understanding of Newtonian Mechanics. In conventional instruction, the gain was only half as large [6].

IV. METHODOLOGY

An educational research with quantitative research modality type and quasi-experimental research design with intact groups is proposed. The instruments for data collection that were used are: a test based on problems, a questionnaire and semi-structured interviews.

The research questions that arise are:

• How peer instruction helps address alternative conceptions that arise in the study of ESR topic?

• What are the alternative conceptions on the subject of ESR?

• How peer instruction influences the teaching-learning process in the topic of study?

• How to develop a class on the topic of ESR based on PI ?

a) Sample selection

In this study, two groups of thirty students enrolled in an Ecuadorian High School participated. Both groups have twenty-six men and four women whose ages ranged between 16 and 17 years.

b) Design of the instrument

A test whose objective is to know what students know about the subject of ESR and identify their conceptions was made.

c) Procedures

The students answered some introductory questions (shown in Annex 1) in order to get information about what they know in the topic of ESR. Then a traditional lecture was given and at the end their task was to solve two problems which main goal was to determine the time dilation and space crunch when an object travels close to the speed of light. The professor asked the students to solve the problem with all the mathematical tools and physics concepts that they know. The test was checked in order to obtain the alternative conceptions. At the end an interview to some students was done. Once the alternative conceptions were identified, the same lecture was given based on the PI methodology.

The solution of the problems are shown in Annex 2.

V. RESULTS AND DISCUSSION

The questionnaire revealed the following alternative conceptions:

a. The concept of "relativity"

One of the questions was: "Describe what you understand by Special Relativity." 20% of the students did not answered and the rest of the students answered pretty much the same, "Everything is relative…". The given answer sounds redundant since then they were asked: "OK. Then what is relative?" and they were not able to respond. The point of

interest here is that the students did not know about the definition of the word "relativity".

b. The name "Einstein" seems not to be a problem

During the test, students were asked "Who is the author of the Special relativity?" The answered was unanimous: "Einstein". Here it is possible to find something inquisitive, the answer that the students gave was right; however, they did not know about the theory or even the word "relativity". In order to find an answer to this fact, an interview was done and the results showed that the communication media plays an important role in the learning process. Most of the students said that they knew the answer because they have watched videos shown on TV or in webpages (like Discovery Channel, Youtube, among others). Other students reported that they have listened from their parents or some relative talking about the topic. Nowadays, there is no doubt that the last name "Einstein" is very famous. Nevertheless, it is important to also stand out his research.

c. Difference between special relativity and general relativity

"$E=mc^2$" is one of the most famous equations and when it was asked to the students one equation related to special relativity, this one was mentioned. During the interview, one student reported: "…I was sure that the equation $E=mc^2$ was right because I read about it in a book… now that I know the answer I am confused and it is hard to understand that $E=mc^2$ belongs to general relativity". Einstein's relativity is classify in special and general. Most of the videos or books that the students were in touch was about relativity (they did not realize that was general relativity) and $E=mc^2$ appears in all of them, notwithstanding they did not notice about the topic in deep. It is important to highlight, when given a lecture regarding Einstein's relativity, that it can be classified in special and general.

d. Application of Special relativity

On the test, it was asked: "Mention one application of Special Relativity". All the students left this answer in blank. It is important to stand out that the students gain a better understanding when they can apply what they learn. Find diverse application in everyday life helps to the learning process. During the interview, one student reported: "At the beginning I was excited in learning relativity. However, I started feeling demotivated when I could not find a way to use in real life, because it seems to be unrealistic how it works…"

e. Postulates of relativity

"What a person see is the light that the objects reflect. Now, imagine that you are on a spaceship that can travel at the speed of light, then what will you see?". This is probably the most difficult question that was addressed. The students reported the following: "…I can't imagine something that goes faster than speed of light…" Another student said: "The laws of Physics must be the same everywhere, but then, why I can not use Newton's law in objects that travel close to the speed of light. Have I been wrong all this time? …" The postulates of relativity confused the high school students mind. Hence, during the lecture, it is recommended to explain with illustrations the postulates at take some time on this point.

f. Difference between the observer and the observed

At the end of the lecture it was asked to solve two problems related with the studied topic. The results showed that 10% did not try to solve the problem, 10% solved properly and 80% of the students could not finish the problem. One big mistake that was found according to the solution that they developed was the recognition between the observer and the observed. In order to get the time dilation due to an object that travels with a speed close to the speed of light, the equation to be used is [13]: $\Delta t = \frac{\Delta t'}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma \Delta t'.$ (1)

During the interview, one student reported: "The problem was easy … the mathematical part was easy to solve, but it was difficult to find the time that belongs to the observer that was moving…"

In the other hand, the second problem asked to get the area of an object that travels at half of the speed of light and the same issue was found, the students have difficulties recognizing the variable of the equations.

$$\Delta l = \Delta l' \sqrt{1-\frac{v^2}{c^2}} = \frac{\Delta l'}{\gamma}. \quad (2)$$

Due this fact, comes the importance of clearly identify in the equation of time dilation (1), the time that belongs to the observer on ground and the one of the observer that is moving. In the same way, it is important to highlight in the equation of space crunch (2), the distance for the observer on ground and for the one that is moving.

VI. PEER INSTRUCTION VS ALTERNATIVE CONCEPTIONS

Once the alternative conceptions were identified, a lecture based on PI as a methodology was developed with a different group of students. The lecture was given by standing out all the points described in section V. The students reported more questions in comparison with the traditional lecture, which is a positive remark as it helps to clear their doubts. When they solved the problem, all of them succeed; and got the correct answer. During the interview one stated: "I love the topic, it seems to be interesting and I feel motivated because now I

understand how the GPS works…" another student stated: "…I think working in pairs is good, it makes me feel comfortable and reliable about myself…"

VII. CONCLUSION

There is no doubt that nowadays, there is much to talk about the relativity of Einstein and by using social media (such as Youtube, Discovery Channel, e-books) it is possible to learn about this important issue. Nevertheless, in the desire to acquire more knowledge about this topic, people tend to create ideas in their minds that sometimes are not correct, due to its complexity.

It is paramount to highlight, when the lecture of Einstein's special relativity takes place, the concept of time dilation and space crunch. The time for the observer on the ground is longer than the time for a moving observer. The space for the observer on the ground is shorter than the space for a moving observer.

On the other hand, the results gotten by applying the peer instruction methodology was positive. It is recommendable for the topic of study. However, further research needs to be done by using other methodologies in order to find the most adequate one.

Alternative conceptions affect the teaching-learning process and it is part of the teacher to find them in order to success in the lecture.

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Annex 1

Questionnaire

1. Describe what do you understand by Special Relativity.
2. Who is the author of this theory?
3. Write down any equation that is related with this theory.
4. Do you know any experiment related with this theory?
5. What do you know about speed of light?
6. Mention one application of Special Relativity.

Annex 2

Problem 1

Two twins are 20 years old. One of them travels from Earth to a star located at $2.4 \times 10^{10} km$ from Earth with a speed of 0.9 *c*. Calculate the time *t* it takes for each twin when the twin reaches the star.

Solution:

For the twin on Earth:

$$t = \frac{d}{v} = \frac{2.4\times10^{10}}{0.9\times3\times10^{6}} s = 88888.9s \approx 24.7\, horas.$$

For the twin that travels:

$$t' = t\sqrt{1-\frac{v^2}{c^2}} = (88888.9s)\sqrt{1-\frac{(0.9c)^2}{c^2}} \approx 10.76\, horas.$$

Problem 2

A rectangle has sides of 0.5 *m* and 0.75 *m* at rest. Suddenly the rectangle starts to move with half of the speed of light, and moves parallel to its longest side. Calculate the area of the rectangle for an observer at rest.

Solution:

Just longest side is going to be affected and the observer will see:

$$a' = a\sqrt{1-\frac{v^2}{c^2}} = 0.75m\sqrt{1-\frac{(0.5c)^2}{c^2}} = 0.324m.$$

Then the area that an observer at rest will see is:

$$A' = a' \cdot b = (0.324m)\cdot(0.5m) = 0.325m^2.$$