LAPEN Symposium: Active Learning of Physics in Latin America

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Abstract. This symposium proposed by the Latin American Physics Education Network (LAPEN) is devoted to show some results on Physics Education research for high school and university level carried out in the Latin-American region. We focus in the Active Learning of Physics methodologies. There are three contributions from Ecuador, Colombia and Mexico: The topics studied are: (1) The teaching of Special Relativity Theory with Peer Instruction, developed in the Escuela Superior Politécnica del Litoral in Guayaquil, Ecuador. (2) Active Learning of Electromagnetism for engineering students, developed in the University Antonio Nariño in Bogota, Colombia. (3) Rasch Analysis and Active Learning of electrical circuits for high school students, developed at the COBAY school Xoclán Plantel, in Mérida Yucatán in the south of Mexico. The Active Learning methodologies are important because there are good results in the literature about their implementation in different educational levels. Besides, it is a way to innovate the physics class, unfortunately in the Latin America region their effectiveness has been little studied. This brief report sheds more light on the matter.

1. Introduction
The Active Learning of Physics in the last thirty years has been one of the most important teaching methodologies because of the excellent results in the students learning. In our research we have chosen three different areas of interest in Physics. First subject is about understanding of Einstein’s Special Relativity \cite{1, 2, 3} using Peer Instruction (PI) \cite{4, 5, 6}, the second one is about the Ohm’s law, Faraday law and electrical circuits \cite{7} using Interactive Lecture Demonstrations \cite{8, 9, 10, 11}, with physical simulations support \cite{12, 13, 14}. The third case deals with the teaching of electrical circuits and Ohm’s law for a high school in Yucatán, México, using Active Learning of Physics. In this work, we present three study cases about Active Learning of Physics in three different countries in Latin America. The first case resumes the results achieved when we use the Peer Instruction to teach Einstein’s Special Relativity for students in the Escuela Superior Politécnica del Litoral (ESPOL) in Ecuador. In the second case, we assess the Electromagnetism student learning in the University Antonio Nariño in Colombia. Finally, in the third case, we make a Rasch analysis for explore the students’ learning of electrical circuits in Xoclán High School in México. These works intend to give us some light on the advantages that these didactic methodologies have for teaching certain Physics topics.
The Rasch model [15, 16, 17, 18, 19, 20] is very useful, to visualize the results using Item Characteristic Curves (ICC). This can help us to analyse the improvement of the groups when we use Active Learning of Physics methodologies.

The paper is organized as follows: Sections 2 and 3 are devoted to the Peer Instruction for learning Einstein’s Special Relativity and some results of this didactic methodology, in a school of Guayaquil, Ecuador. Sections 4 and 5 are devoted to Active Learning in Electromagnetism in an engineering school in Bogotá, Colombia. The results of the applied Rasch model are shown. In the Sections 6 and 7 we show how Active Learning of Physics was implemented in a High School in Mexico, also we include the respective Rasch model. Finally, in Section 8 we present the conclusions.

We want to make a summary of the above, mentioning what are the objectives of these joint works. Summarizing, in the first work we mentioned the advantages that PI has over traditional education, when we teach theoretical concepts of Special Relativity for a group of young university students in Tosagua, Ecuador.

In the second work, the advantages in education are exposed, when we use the Active Learning of Physics for students at the Universidad Antonio Nariño in Bogotá, Colombia. Here the topics of study were electromagnetism, Faraday's law, and electrical circuits.

In the third and last work, the advantages in the educational process were similarly exposed by using the Active Learning of Physics, in topics such as Ohm's law and electric circuits (in series and parallel), adding a didactic prototype built by the students themselves. In this last work, some of the research results are shown, using the Rasch model.

Here, it should be clarified that these results are “local” in nature, and not “global”. In other words, the results obtained from the “easiness parameters” for “each question” of the test, are shown, and not as “a global estimate amount”. Likewise, the ICC are for each question of the test, and not for “all” the test. So, we make the respective conclusion appropriate for these results of “local” character.

We must clarify that the test items (or questions) are not shown here because belong to a validated test and the publication of the test is not allowed, for security reasons, this is so to prevent students to “copy” the test questions, and have the correct answers in advance.

2. Peer Instruction for learning Einstein’s Special Relativity
The students are between 16 to 17 years old (25 senior students, 10 girls and 15 men) and the study is given in a non-governmental high school, located in Tosagua City, Manabi province in Ecuador. We intend that students learn Einstein’s Special Theory of Relativity [1, 2, 3] by means of Peer Instruction at the style of Mazur [4]. The purpose of the study is to determine the effect of PI in the academic performance and the beliefs and attitudes of the students who address the alternative conceptions in the Einstein’s Theory of Special Relativity [5, 6]. The test that we have employed was the Alternative Conceptions Einstein’s Special Relativity Test (ACESRT). The time of the first lecture was of 30 minutes to get attitudes and beliefs of students. Then a pre-test (ACESRT) [6] was applied. Later, the students’ performance was estimated with a post-test (ACESRT), we employed a student’s t for the measure of the new knowledge. Mazur [4], says that PI is a didactic methodology where students study a topic in small groups of two or three students, rather than dealing with the topic alone. There is much evidence in the literature that PI learning and instruction is extremely effective in a wide variety of study subjects and works for a wide range of students, of different personalities and levels. PI consists of a heuristic teaching system supported by a conceptual test, and this allows the student to acquire new knowledge.

The methodology begins with a brief reading on a certain topic. Then a multiple-choice question related with the reading is provided to the students to answer according to their knowledge on the subject, the answer is given with the help of clickers, but recently the student answers with the support of specialty software designed for this purpose.

Based on the results obtained, the teacher then has three options:
1. If the percentage of correct questions is less than 30% then the topic is reviewed again.
2. If the percentage of correct questions is between 30% and 70% then a discussion is organized in pairs, and the student can answer the question again, and the teacher continues giving the answer with a brief explanation.

3. If the percentage of correct questions is greater than 70% then the teacher gives the answer with a brief explanation and can continue with the next topic.

The PI have evidence of its effectiveness, an example of this, was given by Crouch and Mazur [21]. However, we could elaborate a research question for our study case: How improve the teaching performance with PI methodology for high school students?

3. Some results of the PI in the school of Ecuador

We present here some of the results of the beliefs of the students. For example, here we present a sample for a common belief and a desirable attitude of the students, in relation to Special Relativity:

1. (Belief). In the belief of learning Physics’ concepts not giving much interest in the mathematical part: Before the PI the 53.3% of students believe that in order to understand Physics, they needed to have strong mathematical basis; the 34.7% were undecided and 12% were in contrast position in relation at this believe. After applying PI the 17.4% of the students still believe that mathematics are essential to learn physics, and about 80% of the students does not think math is necessary to learn physics, but in relation to the students with indecision they change from 34.7% to 2.6% of the total population of students.

2. (Attitude). Positive interest in learning: Before the PI, the percentages were of 3.0%, 15.0% and 82.0% of students that has not, were undecided and has this attitude, respectively. After applying PI, the first value remained the same and the other two values changed to 13.0% and 84.0%, respectively. We do not know if PI has an impact in this attitude, because there is not a significant variation, before and after applying the PI. But we can assert that there is an increment of students that have major interest in learning the concepts of Special Relativity.

With the aim to clarify how we take the data in this investigation, we mentioned that a test was applied to the students that included questions on topics of Special Relativity, apart from the questions mentioned above. We show some of these topics below.

1. Students do not understand space-time as an only one thing.
2. Students think that the velocity of light in vacuum may vary.
3. Students think that time do not vary, or they think that time is an absolute quantity.
4. Students do not understand well the space crunch equation.
5. Students may think that Special Relativity do not have an application.

We made these questions and covered other essential topics of Special Relativity, with a questionnaire designed for this, and we collected the responses of the students.

First, we apply a pre-test to the two groups (before their instruction) and then a post-test (after their instruction).

To check that the methodology of PI is reliable, we apply a parametric Student’s t. To carry out a Student's t-test, a control group was taken, which was instructed with traditional teaching, and an experimental group, which was instructed with PI. Student's t test gave a value around -13.4 and confidence interval between -2.063 and 2.063, and because the value of t is not inside of the confidence interval, we can say that the null hypothesis (H₀) is rejected. Another method that we can use, to verify this statement, is taking the p-value. When the p-value is greater than 0.05 the null hypothesis is accepted, in this case we obtain a p-value of 1.31064E-12, this value is less than 0.05, then we must reject the null hypothesis.

So, based on the results obtained in the Student's t, we are confident enough to think that the PI methodology to teach Special Relativity concepts is a good methodology and has a reliable teaching effectiveness in the Tosagua high school. Responding favorably to the research question at least in this study case.
By the other hand, we take the Hake-Dellwo model [22, 23] and we obtained a high value of 0.73 when we employ PI, then this methodology brings a high gain learning and we can expect to include this topic in high school curricula. Then, the research question was also answered favourably, for the Hake-Dellwo model.

4. Active Learning in Electromagnetism in Bogotá, Colombia
Here we explore the Active Learning in several themes of electromagnetism, between them are Ohm’s law, electric circuits, and Faraday’s law, with the object to teach these themes to the students of some groups in Antonio Nariño University in Bogotá Colombia. We used the phases of Prediction, Observation, Discussion and Synthesis (PODS) of the Active Learning [7, 8], and we consider the semiotic approach to identify the principal elements in the methodology. Then, we collect the data in two phases, one pre-test (before the application of the methodology), and one post-test (after the application of the didactic methodology of learning) [9, 10, 11]. We used the Hake factor as comparative quantitative indicator [22, 23], the concentration factor as an indicator of students’ thinking model [24] and the Rasch model [15] (which we will describe in more detail in this work) as an indicator of the skills obtained by the students during the process of learning. The applied questions were inspired, in Electric Circuits Conceptual Evaluation (ECCE) [25] and Brief Electricity and Magnetism Assessment (BEMA) [26] validated tests. These two tests can be requested from the PhysPort website [27].

Here we will briefly describe the PODS cycle, which is at the heart of Active Learning of Physics. 
1. Prediction step. The student previously explains the operation of the electrical circuit, in what is called the prediction sheet. This stage is called Prediction, and it is carried out by each student individually.
2. Observation step. The teacher shows the behaviour of the electrical circuit, using the didactic prototype and instruments for measuring electrical quantities.
3. Discussion step. If the student is correct in his prediction, then he does not modify his predictions, but if he is not correct then he needs to modify his predictions. For this, the teacher then divides the group of students into teams of about four participants, so that they can discuss among themselves the electric parameters that they have just observed.
4. Synthesis step. The students representing each team, before the whole group, explain the phenomenon of the electrical circuit. The teacher guides the entire exhibition. The group or many of the students in the group can reach a common conclusion.

In case most of the students do not learn the correct concept, then the cycle repeats once more, until a reasonable percentage of students have learned. We recommend that if less than 70% of the students in the group did not learn the correct concept, then the cycle is repeated, before continuing with other topics.

The research question in this case study is the following: How Active Learning of Physics improve the knowledge level about electrical circuits and Faraday's law of induction in the students of the Antonio Nariño University?

To carry out the research, there is a control group (which will receive traditional teaching) and an experimental group (which will take Active Learning of Physics).

A test is applied to each of the groups before they receive their instruction, this step is known as the pre-test application. Subsequently, a test is applied to each of the groups after they receive their instruction, this step is known as the application of the post-test.

We then collect the responses of the students in each case, in the test, and in this way, we collect the information and data necessary to be able to measure the advantages that Active Learning of Physics may have for the students of the Antonio Nariño University.

The test applied to the groups was designed at the Antonio Nariño University itself [14].

To measure the advancement in knowledge about electrical circuits and Faraday's law of induction that students have when they carry out Active Physics Learning, we use a quantitative method based on
the Rasch model, this model allows us to measure progress in students' knowledge by drawing curves called ICC.

Rasch graphs are curves that measure the probability that a student answers a test question correctly, and this in function of a student parameter called the ability parameter. The greater the student's ability, the greater the probability that he will answer the test question correctly.

Associated with each question in the test there is a difficulty parameter, which weighs the amount of effort that the student must put in to correctly answer the question. The counterpart to the difficulty parameter of the question is called the easiness parameter.

In the following sections we want to show how to apply the Rasch model, to draw ICC curves and compute various parameters of the test and thus help us to estimate the advantages of Active Learning of Physics for students of the Antonio Nariño University.

5. The Rasch model applied in a case study in Antonio Nariño University of Bogota, Colombia

During the years 1960 and 1961, Rasch [15] proposed a model to measure the latent trait of the people with the object to understand its psychological profile. Now in knowledge area, we can estimate the ability parameter of the people. Rasch model [16] corresponds to the modern Item Response Theory and can help us to assess the learning of the students that have learned the concepts using an active learning methodology. Rasch model provides us with some ICC, which give us the probability $P(X_{ij}=1|\theta_i, \delta_j)$ that the $i$-th student have a correct answer in the test, as a function of the difficulty parameter $\delta_j$ of the question, given the ability parameter $\theta_i$ of the student number $i$. The mathematical relation between $P$, $\theta_i$, and $\delta_j$, giving a set of discriminant constants $X_{ij}=1$, is given by

$$P(X_{ij}=1|\theta_i, \delta_j) = \frac{\exp(X_{ij}(\theta_i - \delta_j))}{1 + \exp(X_{ij}(\theta_i - \delta_j))} = \frac{\exp(\theta_i - \delta_j)}{1 + \exp(\theta_i - \delta_j)}.$$  \hspace{1cm} (1)

In the following results we consider 5 questions (ranging from Q1 to Q5) of the original test (the original test was of 23 questions, and have various themes of electromagnetism), that deal with electrical circuits, Ohm’s law and Faraday’s law.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 |
|---------|----|----|----|----|----|
| 1       | 1  | 0  | 0  | 0  | 0  |
| 2       | 1  | 0  | 0  | 0  | 0  |
| 3       | 0  | 0  | 1  | 0  | 0  |
| 4       | 0  | 1  | 0  | 0  | 0  |
| 5       | 0  | 0  | 0  | 0  | 0  |
| 6       | 1  | 0  | 1  | 0  | 0  |
| 7       | 1  | 0  | 1  | 0  | 0  |
| 8       | 1  | 0  | 0  | 0  | 0  |
| 9       | 1  | 0  | 1  | 0  | 0  |
| 10      | 0  | 1  | 1  | 1  | 0  |

We collect a sample of 10 students of each group (control and experimental group) to show the results. We focus in the Rasch analysis and extract the difficulty parameters of the test using the eRm (Extended Rasch Model) package of the R software. “R” is a programming language designed for statistical analysis (you can visit its web page [28]). The package eRm use the function called “RM” to estimate the difficulty parameters, given a table of dichotomous data recollected from the group and
similar to the table 1 (Corresponding to the sample of students of the control group in the pre-test). The algorithm used by the software package is based on the “conditional maximum likelihood” (CML) estimation [16], as is shown in internal “R” self-documentation (or inline help of the program).

We want to explain the values of table 1, with some simple examples: We write a “1” for the first row (the first student) and the first column (question Q1 of the test), because the student 1 answers correctly the first question. We annotate a “0” in the first row and second column, because the student 1 answers incorrectly the second question of the test. Similarly, we write the other entries. The table then, only have two types of values (“1” and “0”), and this is the reason why the Rasch model is said to be dichotomous.

The original units for the scale of ability and difficulty parameters are named “logits”, so we need to reinterpret the results. We can follow the criteria of Baker and Kim [17], who have made the following classification of table 2, for the difficulty parameters.

In table 3, we show a basic calculation of the difficulty parameters of the questions. Note that the algorithm cannot calculate some parameters because some data in the source table remain constant always. The conditional log-likelihood is of -9.961544. The number of iterations is 11 and the number of parameters is 3. The confidence interval (or CI) is about 0.95 (or 95%), we recommend seeing for example Hagell [29], to understand the details of the CI.

The Linear Logistic Test Model (LLTM), was proposed by Fisher [30], and is considered as derived from Rasch model; the Rasch equation (1), under this consideration is written as

\[ P(X_{ij} = 1|\theta, w_j, \eta_k) = \frac{\exp(\theta - \sum_{k=1}^{K} w_k \eta_k)}{1 + \exp(\theta - \sum_{k=1}^{K} w_k \eta_k)} \]  
(2)

Where we have replaced the difficulty parameter \(\delta_j\) by a lineal combination of weight factors \(w_k\) and basic parameters \(\eta_k\) of the LLTM [16, 31]:

\[ \delta_j = \sum_{k=1}^{K} w_k \eta_k \]  
(3)

On the other hand, we explain here how we can get the data in table 3 and 4, using R software. Suppose we store the data from table 1 in a variable of R named “x1con_pre”, that is, the recollected data of the control group in the pre-test. If the reader has trouble passing the data from a table to the R program, then we recommend reading an R guide, such as the one written by Tilman [32]. With the aim to produce the data of table 3 we open the R program, load this variable, and issue the following three commands:

```r
> install.packages("eRm")
> library(eRm)
> summary(LLTM(x1con_pre, 0.95))
```

The first command installs the eRm package in R; the second command, load the library eRm, and the third, reproduce the values given in table 3 and in table 4, using the LLTM algorithm of the CML estimation, with the 95% of CI, and using the data showed in table 1. The function “summary” is issue for displaying purposes of the results. In table 3, we only need the first numerical column named “Estimate”, the others indicate the “standard errors” and the CI of the first column. The CI is between the two values of columns titled “lower CI” and “upper CI”. The column named “Criteria” of table 3, takes the value of “Estimate” column, and then classifies it according the general criteria showed in table 2.
Table 2. General criteria to classify the difficulty parameters of the items.

| Difficulty parameter | Criteria      |
|----------------------|--------------|
| $\delta < -2.625$    | Very easy    |
| $-2.625 \leq \delta < -1.5$ | Easy       |
| $-1.5 \leq \delta < 1.5$ | Medium     |
| $1.5 \leq \delta < 2.625$ | Hard       |
| $2.625 \leq \delta$    | Very hard    |

The algorithm also computes the complementary easiness parameters with the same 0.95 of confidence interval (CI) [29]; we show this data, in table 4. Here, we can calculate 4 values of the easiness parameters according to Rasch model and the algorithm CML [16].

Table 3. Basic parameters ($\eta$) of the LLTM for the control group in their pre-test with 0.95 CI.

| $\eta$ | Estimate $\eta$ | Std. Error | lower CI | upper CI | Criteria |
|--------|-----------------|------------|----------|----------|----------|
| $\eta_1$ | -0.579          | 0.690      | -0.774   | 0.774    | Medium   |
| $\eta_2$ | 0.790           | 0.597      | -0.380   | 0.380    | Medium   |
| $\eta_3$ | -1.361          | 0.848      | -0.301   | 3.023    | Medium   |

Further, we can continue and calculate the basic and easiness parameters of the same sample group of control for the post-test, and also, we can compute the basic and easiness parameters of the items for the experimental group (the group that led the Active Learning of Physics), in their pre-test and the post-test phases.

Table 4. Easiness parameters of control group in their pre-test with 0.95 CI.

| Item | Estimate | Std. Error | lower CI | upper CI | Criteria |
|------|----------|------------|----------|----------|----------|
| Q1   | 1.150    | 0.605      | -0.035   | 2.336    | Medium   |
| Q2   | -0.579   | 0.690      | -1.932   | 0.774    | Medium   |
| Q3   | 0.790    | 0.597      | -0.380   | 1.959    | Medium   |
| Q4   | -1.361   | 0.848      | -3.023   | 0.301    | Medium   |

This was the analysis of the pre-test, in control group. Later the teacher follows the methodology of Active Learning of Physics to teach electrical circuits and Faraday’s law. Apply the same selected test of 5 questions and recollect the data of the responses of their students.

For a sample of 10 students and a test of 5 selected questions, the answers of the students are showed in table 5. The rows are numbered from 1 to 10 and represent each student of the control group. The columns are 5 because we apply a simple test of 5 selected questions, about electrical circuits, and Faraday’s law. We do not write here the explicit questions, but we refer the lector to the reference [14], for the details.
Table 5. Brief sample of control group responses in their post-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 |
|---------|----|----|----|----|----|
| 1       | 0  | 1  | 1  | 0  | 1  |
| 2       | 0  | 1  | 1  | 1  | 0  |
| 3       | 1  | 0  | 1  | 0  | 1  |
| 4       | 1  | 0  | 0  | 1  | 0  |
| 5       | 1  | 1  | 0  | 1  | 1  |
| 6       | 1  | 0  | 1  | 1  | 1  |
| 7       | 1  | 1  | 1  | 1  | 1  |
| 8       | 1  | 1  | 1  | 1  | 1  |
| 9       | 0  | 1  | 1  | 1  | 0  |
| 10      | 0  | 0  | 0  | 1  | 1  |

Suppose we store the data from table 5 in a variable of R named “x1con_post”, that is, the recollected data of the control group in the post-test. In order to produce the data of table 6 and 7 we open the R program, load this variable, and issue the following two commands:

```r
> library(eRm)
> summary(LLTM(x1con_post, 0.95))
```

Then we use again the LLTM algorithm at 95% (or 0.95) of the CI, to compute the difficulty parameters of post-test phase. These basic parameters values are in the “Estimate $\eta$” column of table 6. In table 7 we show the easiness parameters in the column named “Estimate”. We do not use the other columns because these other columns of table 6 and table 7 are related with standard errors and limits of the applied CI.

Table 6. Basic parameters ($\eta$) of the LLTM for the control group in their post-test with 0.95 CI.

| $\eta$ | Estimate $\eta$ | Std. Error | lower CI | upper CI | Criteria |
|--------|----------------|------------|----------|----------|----------|
| $\eta_1$ | -0.371 | 0.596 | -1.538 | 0.797 | Medium |
| $\eta_2$ | 0.073 | 0.613 | -1.129 | 1.275 | Medium |
| $\eta_3$ | 0.595 | 0.676 | -0.730 | 1.921 | Medium |
| $\eta_4$ | 0.073 | 0.613 | -1.129 | 1.275 | Medium |

Table 7. Easiness parameters of control group in their post-test with 0.95 CI.

| Item | Estimate | Std. Error | lower CI | upper CI | Criteria |
|------|----------|------------|----------|----------|----------|
| Q1   | -0.371   | 0.596      | -1.538   | 0.797    | Medium   |
| Q2   | -0.371   | 0.596      | -1.538   | 0.797    | Medium   |
| Q3   | 0.073    | 0.613      | -1.129   | 1.275    | Medium   |
| Q4   | 0.595    | 0.676      | -0.730   | 1.921    | Medium   |
| Q5   | 0.073    | 0.613      | -1.129   | 1.275    | Medium   |

Finally, we can resume the differences between pre-test and post-test phases in the sample control group and make a comparative analysis of the basic parameters and easiness parameters. This is done in table 8 and 9.
Table 8. Basic parameters ($\eta$) of the LLTM and their difference between pre-test and post-test phases of the sample in control group. We appreciate some changes.

| $\eta$ | Pre-test $\eta$ | Post-test $\eta$ | Difference | Criteria |
|--------|-----------------|-----------------|------------|---------|
| $\eta_1$ | -0.579         | -0.371          | 0.208      | Medium  |
| $\eta_2$ | 0.790           | 0.073           | -0.717     | Medium  |
| $\eta_3$ | -1.361          | 0.595           | 1.956      | Hard    |
| $\eta_4$ | -              | 0.073           | -          | -       |

Table 9. Easiness parameters and difference between pre-test and post-test phases of the sample in control group. We appreciate some changes.

| Item | Pre-test | Post-test | Difference | Criteria |
|------|----------|-----------|------------|---------|
| Q1   | 1.150    | -0.371    | -1.521     | Hard    |
| Q2   | -0.579   | -0.371    | -0.95      | Medium  |
| Q3   | 0.790    | 0.073     | -0.717     | Medium  |
| Q4   | -1.361   | 0.595     | 1.956      | Easy    |
| Q5   | -        | 0.073     | -          | -       |

We repeat the procedure for the experimental group and calculate the differences between pre-test and post-test phases, and then we have the tables 12 and 13 of the analysis with Rasch model.

In table 10 we show the responses of a sample of experimental group in the pre-test phase, i.e., before we apply the Active Learning of Physics, for this sample.

In table 11 we show the responses of the same sample of the experimental group in the post-test phase, i.e., when we apply the same test of five selected questions about circuits and Faraday’s law.

Table 10. Brief sample of experimental group responses in their pre-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 |
|---------|----|----|----|----|----|
| 1       | 0  | 1  | 1  | 1  | 0  |
| 2       | 0  | 0  | 0  | 0  | 0  |
| 3       | 0  | 0  | 0  | 0  | 0  |
| 4       | 0  | 0  | 0  | 0  | 0  |
| 5       | 0  | 0  | 1  | 1  | 0  |
| 6       | 0  | 0  | 0  | 0  | 1  |
| 7       | 0  | 0  | 0  | 0  | 0  |
| 8       | 1  | 0  | 0  | 0  | 0  |
| 9       | 0  | 1  | 0  | 0  | 0  |
| 10      | 0  | 0  | 1  | 1  | 0  |
Table 11. Brief sample of experimental group responses in their post-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 |
|---------|----|----|----|----|----|
| 1       | 1  | 1  | 1  | 1  | 1  |
| 2       | 1  | 1  | 1  | 1  | 1  |
| 3       | 1  | 1  | 1  | 1  | 0  |
| 4       | 1  | 1  | 1  | 1  | 0  |
| 5       | 1  | 0  | 1  | 1  | 1  |
| 6       | 1  | 1  | 1  | 0  | 1  |
| 7       | 1  | 1  | 1  | 1  | 1  |
| 8       | 1  | 1  | 1  | 0  | 0  |
| 9       | 0  | 1  | 1  | 0  | 1  |
| 10      | 1  | 1  | 1  | 0  | 0  |

Here, we have several computed parameters of 4 for the pre-test and 3 for the post-test. We have a numeric quantity named “log-likelihood” of -10.3 for the pre-test and -6.8 for the post-test. Then, we obtain better results in post-test phase than in the pre-test, for the experimental group.

Table 12. Basic parameters ($\eta$) of the LLTM and their difference between pre-test and post-test phases of the sample in experimental group. We appreciate some changes.

| $\eta$  | Pre-test $\eta$ | Post-test $\eta$ | Difference $\eta$ | Criteria |
|---------|-----------------|-----------------|-------------------|----------|
| $\eta_1$ | 0.094          | 0.556           | 0.462             | Medium   |
| $\eta_2$ | 0.704          | -0.252          | -0.956            | Medium   |
| $\eta_3$ | 0.704          | -0.860          | -1.564            | Easy     |
| $\eta_4$ | -0.751         |                | -                 | -        |

There is no great difference between the quantities listed in table 13 for the experimental group and table 9 of the control group, but for the easiness parameters of the experimental group there are 4 positive increments, and for the control group, there are just one positive difference. Then in some sense, and with this reduce set of information; we can conclude that the experimental group have learnt the physics’ concepts better, than the control group.

Table 13. Easiness parameters and difference between pre-test and post-test phases of the sample in experimental group. We appreciate some changes.

| Item | Pre-test $\eta$ | Post-test $\eta$ | Difference $\eta$ | Criteria |
|------|-----------------|-----------------|-------------------|----------|
| Q1   | -0.751          | 0.556           | 1.307             | Medium   |
| Q2   | 0.094           | 0.556           | 0.462             | Medium   |
| Q3   | 0.704           |                | -                 | -        |
| Q4   | 0.704           | -0.252          | 0.956             | Medium   |
| Q5   | -0.751          | -0.860          | -0.109            | Medium   |

Another analysis of the data can be achieved, with the plot of the ICC, to show graphically the differences already presented here with the tables of parameters of easiness, of the two groups. We use the “ltm” (latent trait model) package of R software to get the ICC graphics [17].
In the figures 1 and 2 we show the ICC for the sample of the control group, the figure 1 correspond to the pre-test phase, and figure 2 to the post-test phase. We note that the curves move upward from pre-test to post-test, which indicate an improvement when answering the test questions. Each annotation “Q1”, “Q2”, . . . in the curves is used to identify the number of the question (or item) in the applied test. The redaction of each test question is not shown, for security reasons, because the students could copy the question, and in advance find out the correct answer. We can request the redaction of each question on the website of PhysPort [27], and asking for the corresponding test (in this case, ECCE).

Figure 1. ICC for the sample of the control group in pre-test. The probability of success in each item is show.

![ICC for sample of control group in pre-test](image)

Figure 2. ICC for the sample of the control group in post-test. The probabilities of a correct response were raised with respect to the pre-test phase.

![ICC for sample of control group in post-test](image)

The method to obtain the ICC curves in R is the following, suppose x1con_pre have the data of table 1, and then we fixed the discrimination parameter to 1, and make the following call to calculate the difficulty parameters of the applied test for the table 1

```r
> install.packages("ltm")
> library(ltm)
> rasch(x1con_pre, constraint=cbind(ncol(x1con_pre)+1,1))
```

Where the first line installs the ltm package in R, the second line call the ltm library, and the third calculate the difficulty parameters with a discrimination parameter of 1. We can ask for help to R about the parameters of function “rasch” with the following call in R

```r
> ?rasch
```

And R display its help for the function “rasch”, we employ the “?” sign before the name of the function “rasch” to know how we can use it in R.

We then keep this information in the variable y1con_pre with the assign operator of R

```r
> y1con_pre <- rasch(x1con_pre, constraint=cbind(ncol(x1con_pre)+1,1))
```
Then we ask to the ltm package to do a graph of the ICC with these difficulty parameters, and we make the following call in R:

```r
> plot(y1con_pre, type="ICC")
```

In this way we have obtained the ICC curves of Figure 1. We proceed in similar way with the data of table 5 for the control group in the post-test phase and obtain the figure 2.

Figures 3 and 4 are the ICC curves for the experimental group, i.e. the group that follows the Active Learning of Physics. Figure 3 is for the pre-test phase and figure 4 is for the post-test phase. In the two phases we have applied the same test of 5 selected questions.

In the figures 3 and 4, we show the ICC of Rasch model, for the sample of the experimental group. The figure 3 corresponds to the pre-test phase, and figure 4 to the post-test phase. We note that the curves move upward from pre-test to post-test, this fact, indicate an improvement when answering the test question in the experimental group. Then, there is a clear learning process for the students, from pre-test to post-test.

We note that the figures 2 and 4 show the post-test phases of the samples of control and experimental groups, respectively. The chances of correct response are significantly better for the experimental group than for the control group. Then we can conclude that the didactic methodology of Active Learning produces better results than traditional teaching.

However, in the active methodology, students work more, than in traditional teaching, and typically require more effort from both students and teacher. Due to these disadvantages of Active Learning of Physics, we recommend applying it once a week or every fifteen days.

So, the most appropriate recommendation that we find would be to combine Active Learning of Physics with traditional teaching, to improve the distribution of study times.

---

**Figure 3.** ICC for the sample of the experimental group in pre-test. The probability of success in each item is show.

**Figure 4.** ICC for the sample of the experimental group in post-test. The probabilities of a correct response were raised with respect to the pre-test phase.
6. Active Learning in México

In Yucatán, México, the average evaluation in academic studies is of 8.8 on a scale from 0 to 10, and the students are aged about 15 years old, which is equivalent to a little more than a second year of secondary school. The national approval rate average is 9.2 of every 100 people aged 15 and over (this data, are in accordance with the information found in the archives of the “Instituto Nacional de Estadística y Geografía”, or INEGI [33], for the year 2018 in Yucatán, México):

- They do not have degree of schooling: 6.7%.
- They have finish basic education: 55.0%.
- They finish upper secondary education: 19.9%.
- They concluded higher education: 18.2%.
- Not specified: 0.2%.

Table 14 resumes the information of levels of education in Yucatán and the rest of México, taken from the INEGI.

We will analyse the results of electrical circuits in a High School, where the teaching of Physics is given in a traditional way, i.e., is based on the unidirectional instruction where the teacher exposes, explains and solves problems.

We propose then Active Learning of Physics based on Sokoloff method [7] of PODS cycle (Prediction, Observation, Discussion, Synthesis) and the Interactive Lecture Demonstrations [8], together with an electrical circuit prototype (built by the students themselves) as support material for the didactic activity. The theme of study is electricity, Ohm’s law and the construction of elemental series and parallel circuits. We then employ a didactic prototype to teach electrical circuits to the students. In this work we have a control group and an experimental group, the last of which will have instruction with the help of Active Learning. The first group will follow the traditional teaching; we call it “control group”. The second group will take the didactic methodology of Active Learning of Physics to learn the same study topics, and we will call it the “experimental group”. We also explore our results, employing again, the Rasch model [16], and using the R programming language or “R software” [17, 20].

In this case study, we have the following research question: How improve the Active Learning of Physics the understanding of electrical circuits and Ohm's law in students of the Xoclán campus in Yucatán, Mexico?

| School modality          | 2015-2016 (%) | 2016-2017 (%) | 2017-2018 (%) | National (%) |
|--------------------------|---------------|---------------|---------------|--------------|
| Higher Middle Education  |               |               |               |              |
| Dropping out of school   | 14.1          | 13.9          | 17.7          | 12.3         |
| Reprobation              | 19.0          | 18.6          | 18.3          | 13.4         |
| Terminal efficiency      | 60.6          | 62.2          | 64.1          | 66.6         |

To collect the data from the control group, we first applied a prepared test before teaching the students through traditional teaching. We take note of the answers that the students give to each question of the test, and we write them in a two-dimensional table. We call this step the pre-test. We follow a Rasch dichotomous model, so the students' responses to each test question can be correct or incorrect. We write the correct answers with a one “1” in a table, and the wrong ones we record with a zero “0” in a 2x2 data table. The columns of the table represent each question on the test, and the rows represent each student in the group. We suggest seeing table 1 that exemplifies how the data is collected.
Once they have received a traditional class, the same test is applied to the group, to see the knowledge improvement in electrical circuits and Ohm's law, this step is called the post-test.

We follow the same procedure to collect the data from the experimental group, only in this case, the students follow the steps of Active Learning of Physics to learn the concepts of electrical circuits and Ohm's law.

In the following sections we discuss the results of the analysis of the collected data when we use the Rasch model.

At this point in this work, it is convenient to clarify some points about the Rasch model. The Rasch model is very extensive and is currently highly developed. We want to point out that in this work, we will focus on obtaining the ICC graphs, and the parameters of difficulty and easiness of the test questions, and we hope that with these results we will have enough support to appreciate the advantages of Active Learning of Physics in this particular case study.

Another aspect that should be noted about the Rasch curves or ICC curves, is in the height they take when they are drawn. Since the higher the height, there is a greater probability that the student will answer the test question well, which means that the student's knowledge is better.

7. Rasch model for Active Learning of Physics in the Xoclán High School in Yucatán, México

One way to measure the progress in the group learning is to use the easiness parameters that are part of the Rasch model theory [16]. We can use R [17, 20], to be able to extract these numbers from the data of the results of the test before applying the methodology or traditional teaching, and after applying the corresponding teaching method. The parameters of easiness are show in the tables 19 and 20. We can note that the two groups have a progress in their knowledge of the electrical circuits. Nevertheless, we note that there are better results in the experimental group, than in the control group.

![Figure 5. ICC for the sample of the control group of Xoclán plantel of Yucatán, México in pre-test. The probability of success in each item is show.](image1.png)

![Figure 6. ICC for the sample of the control group of the Xoclán plantel of Yucatán, México in the post-test. The probabilities of a correct response were raised with respect to the pre-test phase.](image2.png)
These results in easiness parameters, suggest to us that the use of active teaching methods has advantages in student learning, compared to the use of traditional teaching.

As the results are local to each question of the test applied, we have issued a conclusion at the end of this work, according to the results shown.

The applied test was based in 13 questions of ECCE [25], and 2 questions from a local book named Physics II [34]. In total 15 questions were applied in the two phases (pre-test and post-test).

We have taken a brief sample of 5 students in each of our groups, and then we apply the test, before the instruction in the control and experimental groups. In tables 15 and 17 we show the collected data of the answers of the students, showing its preliminary knowledge about electrical circuits and Ohm’s law. These data are a sample of how we collect the data in both groups. As we can see, the tables are rectangular arrangements with zeros and ones as inputs. We will explain how to interpret these dichotomous data. For example, a one “1” for the second student who answered question two “Q2” of the test in the control group means that the second student answered the second question “Q2” of the test correctly in the control group. To give another example, a zero “0” for the first student who answered question one “Q1” of the test in the control group means that the second student answered incorrectly the first question “Q1” of the test in the control group.

We then apply traditional teaching to the control group, and then collect the data of the answers of the students to the same test of 15 questions; the table 16 shows this collected data.

### Table 15. Brief sample of control group responses in their pre-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 |
|---------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| 1       | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1   | 1   | 1   | 1   | 1   | 0   |
| 2       | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0   | 0   | 0   | 0   | 1   | 0   |
| 3       | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 1   |
| 4       | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 1   | 1   |
| 5       | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 1   | 1   | 1   | 0   | 0   | 1   |

### Table 16. Brief sample of control group responses in their post-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 |
|---------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| 1       | 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1   | 0   | 1   | 1   | 1   | 1   |
| 2       | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1   | 0   | 1   | 1   | 0   | 1   |
| 3       | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1   | 0   | 1   | 1   | 1   | 1   |
| 4       | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 1   | 1   | 1   | 1   | 0   | 0   |
| 5       | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 1  | 1   | 0   | 0   | 1   | 1   | 1   |

We apply Active Learning of Physics to the experimental group, and then collect the data of the answers of the students to the same test of 15 questions about electrical circuits and Ohm’s law; the table 18 shows this collected data.

### Table 17. Brief sample of experimental group responses in their pre-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 |
|---------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| 1       | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1   | 0   | 0   | 0   | 0   | 0   |
| 2       | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0   | 0   | 0   | 0   | 0   | 1   |
| 3       | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0   | 1   | 0   | 0   | 0   | 1   |
| 4       | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 1   |
| 5       | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 1   | 1   |
Table 18. Brief sample of experimental group responses in their post-test.

| Student | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 |
|---------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| 1       | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0   | 0   | 1   | 0   | 1   |
| 2       | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1   | 1   | 0   | 1   | 0   |
| 3       | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0   | 1   | 1   | 1   |
| 4       | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0   | 0   | 1   | 0   | 1   |
| 5       | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1   | 1   | 1   | 1   |

To obtain the results of Tables 19 and 20, we follow a procedure very similar to that set forth in section 5, so for reasons of space, we have decided to omit these details, in this case.

Table 19. Easiness parameters and difference between pre-test and post-test phases of the sample in control group. We appreciate some changes.

| Item | Pre-test | Post-test | Difference | Criteria |
|------|----------|-----------|------------|----------|
| Q1   | -        | -1.679    | -          |          |
| Q2   | 0.182    | -         | -          |          |
| Q3   | -0.823   | -1.679    | -0.856     | Medium   |
| Q4   | -        | 0.197     | -          |          |
| Q5   | -        | -1.679    | -          |          |
| Q6   | 1.016    | 1.230     | 2.053      | Easy     |
| Q7   | -0.823   | 1.230     | 2.053      | Easy     |
| Q8   | 0.182    | 0.197     | 0.015      | Medium   |
| Q9   | 0.182    | 1.230     | 1.048      | Medium   |
| Q10  | 0.182    | 1.230     | 1.048      | Medium   |
| Q11  | 0.182    | -0.674    | -0.856     | Medium   |
| Q12  | 0.182    | 0.197     | 0.015      | Medium   |
| Q13  | -0.823   | 1.230     | 2.053      | Easy     |
| Q14  | 0.182    | 0.197     | 0.015      | Medium   |
| Q15  | 0.182    | -         | -          |          |

If we examine the table 19, for example, we see that the easiness parameters of the post-test in the control group are in general mayor that the corresponding parameters for the pre-test, this can be easily seen from the table.

Table 20. Easiness parameters and difference between pre-test and post-test phases of the sample in experimental group. We appreciate some changes.

| Item | Pre-test | Post-test | Difference | Criteria |
|------|----------|-----------|------------|----------|
| Q1   | -0.873   | 0.895     | 1.768      | Easy     |
| Q2   | 0.816    | -         | -          |          |
| Q3   | -        | -         | -          |          |
| Q4   | -0.873   | -0.851    | 0.022      | Medium   |
| Q5   | -0.873   | 0.895     | 1.768      | Easy     |
| Q6   | 0.058    | -         | -          |          |
| Q7   | -0.873   | -0.851    | 0.022      | Medium   |
| Q8   | -0.873   | -         | -          |          |
| Q9   | 1.743    | -         | -          |          |
| Q10  | 0.058    | -         | -          |          |
| Q11  | -        | -0.066    | -          |          |
| Q12  | 0.816    | -0.851    | -1.667     | Hard     |
| Q13  | -        | 0.895     | -          |          |
| Q14  | 0.816    | -0.066    | -0.882     | Medium   |
| Q15  | 0.058    | -         | -          |          |
In table 19 we see that also the experimental group improves with the Active Learning. Some of the values cannot be computed by the LLTM method, because some columns or rows have only one value (0 or 1), which represent one irregularity in the data set. We use (this time), the LLTM function of the eRm package of R software to compute these values of item easiness, in tables 15 and 16.

If we assume that “M” is the matrix of responses of the students (see an example of this kind of matrix, in table 15, for a test of 15 questions: “Q1”, . . . , “Q15”), then we get the “easiness item parameters” of tables 19 and 20 by calling “summary(LLTM(M))”. We can see the help for LLTM function, by asking for help with the call “help(LLTM)” in an R session. The table 19 show the difference in easiness parameters for the control group, similarly table 20 show the difference in easiness parameters in experimental group. The table 19 show us two items with easy criteria in the difference of parameters, while table 20 show us two items with easy criteria in the difference and one with hard criteria. Also, table 19 show us seven items with medium criteria in the difference of parameters, while table 20 show us three items with medium criteria in the difference of parameters. Then the LLTM approximation of Fisher fails five times in table 19 and fails nine times in table 20, and this is because the nature of the data. Nevertheless, in table 20 we have two “easy” criteria, and one “hard” criteria and in table 19 we only have two “easy” criteria. Here the our criterion with the LLTM method and tables 19 and 20 does not seem to be a good criterion to determine if Active Learning of Physics is a better methodology than traditional teaching.

Other results that suggest that the active methodology is a little better than the traditional methodology, is observing the ICC curves of figures 6 and 8. There are several ICC curves of figure 8 that show a better probability that the student answers the questionnaire correctly, than the probabilities showed in several curves of figure 6.

Therefore, the Rasch model has better graphic results for the experimental group than for the control group. Which suggests that Active Physics Learning has achieved better results, with students, than traditional teaching.

**Figure 7.** ICC for the sample of the experimental group of Xoclán High School of Yucatán, México in pre-test. The probability of success in each item is show.

**Figure 8.** ICC for the sample of the experimental group of Xoclán High School of Yucatán, México in the post-test. The probabilities of a correct response were raised with respect to the pre-test phase.
We are now going to briefly describe how we obtained the ICC curves of figures 5, 6, 7 and 8. Suppose we need figure 5. If “x1con_pre” is the matrix that contains the data from table 15; then in R we make the following calls

```r
> install.packages("ltm")
> library(ltm)
> y1con_pre <- rasch(x1con_pre, constraint=cbind(ncol(x1con_pre)+1, 1)
```

Then “y1con_pre” will contain the necessary information of the test difficulty parameters for the control group in the pre-test.

The first command installs the “ltm” package in R. The second command loads the “ltm” library and the third calculates the test difficulty parameters for the control group in the pre-test, with a constraint of a discriminant parameter \(X_g\) of “1”.

As we already know the difficulty parameters, we can graph the ICC curves of the control group for the pre-test, that is, we can obtain the ICC curves of figure 5; in order to ask R to graph these curves, we make the following call on the R command line:

```r
> plot(y1con_pre, type="ICC")
```

To better understand the details of this process, we recommend that the reader review the book by Baker and Kim [17], and the “ltm” manual [35].

We continue the analysis plotting the ICC in each case (using the “ltm” package [17]) and comparing the results. The probabilities of a correct response in Figs. 6 and 8 were raised with respect to the pre-test phase (Figs. 5 and 7).

| Item | Pre-test \(\delta\) | Post-test \(\delta\) | Difference |
|------|------------------|-----------------|-----------|
| Q1   | -24.566          | -1.577          | 22.990    |
| Q2   | -0.462           | 24.566          | 25.029    |
| Q3   | -1.554           | -1.577          | 0.023     |
| Q4   | -24.566          | 0.467           | 25.034    |
| Q5   | -24.566          | -1.577          | 22.990    |
| Q6   | 0.457            | 24.566          | 24.109    |
| Q7   | -1.554           | 1.577           | 3.130     |
| Q8   | -0.462           | 0.467           | 0.930     |
| Q9   | -0.462           | 1.577           | 2.039     |
| Q10  | -0.462           | 1.577           | 2.039     |
| Q11  | -0.462           | -0.468          | -0.005    |
| Q12  | -0.462           | 0.468           | 0.930     |
| Q13  | -1.554           | 1.577           | 3.130     |
| Q14  | -0.462           | 0.467           | 0.930     |
| Q15  | -0.462           | 24.566          | 25.029    |

Tables 21 and 22 list the difficulty parameters (\(\delta\)) and difference between pre-test and post-test phases of the sample in control group.

Tables 21 and 22 list the difficulty parameters (\(\delta\)) using the ltm package of R for the control and experimental groups. Table 21 list the difficulty parameters of the control group in pre-test and post-test phases, the pre-test column corresponds with the ICC curves of figure 5, the post-test column correspond with the ICC curves of figure 6. Table 22 list the difficulty parameters of the experimental group in pre-
test and post-test phases, the pre-test column corresponds with the ICC curves in figure 7, and the post-test column corresponds to the ICC curves in figure 8.

Once we have the difficulty parameters and assume that the discrimination coefficients are reduced to unity, we can find the ICC curves corresponding to those values by using equation (1).

Which expresses the relationship that Rasch found between three quantities: the item's difficulty parameter (delta, $\delta_i$), the student's ability parameter (theta, $\theta_j$), and the probability that the student answers correctly to that item on the test $P(X_{ij} = 1|\theta_j, \delta_i)$.

### Table 22. Difficulty parameters ($\delta$) and difference between pre-test and post-test phases of the sample in experimental group.

| Item | Pre-test $\delta$ | Post-test $\delta$ | Difference |
|------|------------------|-------------------|------------|
| Q1   | -1.500           | 1.556             | 3.056      |
| Q2   | 0.442            | 24.566            | 24.124     |
| Q3   | -24.566          | 24.566            | 49.132     |
| Q4   | -1.500           | -0.461            | 1.040      |
| Q5   | -1.500           | 1.556             | 3.056      |
| Q6   | -0.443           | 24.556            | 25.009     |
| Q7   | -1.500           | -0.461            | 1.040      |
| Q8   | -1.500           | 24.556            | 26.066     |
| Q9   | 1.500            | 24.556            | 23.066     |
| Q10  | -0.443           | 24.556            | 25.009     |
| Q11  | -24.566          | 0.460             | 25.026     |
| Q12  | 0.442            | -0.461            | -0.903     |
| Q13  | -24.566          | 1.556             | 26.122     |
| Q14  | 0.442            | 0.460             | 0.018      |
| Q15  | -0.443           | 24.556            | 25.009     |

The figures 5 and 6 show us in a graphical form that the group of control in post-test have improved their score, because the curves in post-test show comparatively more probability of a correct response that the corresponding curves of the control group in their pre-test phase [17]. The same situation is repeated in a similar way for the pre-test vs. post-test phases for the experimental group, as we can see in figures 7 and 8. Nevertheless, the heights of the curves in post-test phase for the experimental group are comparatively greater than the heights of the curves of the post-test phase for the control group. Here, we finalize the analysis of our results using the Rasch model.

### 8. Conclusions

We show here three cases of Learning of Physics in three different countries of Latin America. In the three case studies, we first applied a pre-test to the control and experimental groups (before receiving the instruction), and then a post-test was applied (after receiving the instruction).

In the first case, we show the Peer Instruction [4] as a methodology that results effective to teach the concepts of Special Relativity for the students of a high school situated in Tosagua city in Manabí province in Ecuador, we used the Hake-Dellwo criteria [22, 23] to suggest this conclusion over the recollected data, also we use Student’s $t$ test, with favourable results.

In the other two cases, we use the Rasch model to show the effectiveness of Active Learning of Physics with the PODS cycle and the Interactive Lecture Demonstrations applied in two different regions of Latin America. The first region was a school of Bachelor’s degree in Bogotá, Colombia, and the last one was a high school in Mérida, Yucatán, México. In Bogotá we treated the themes of Ohm’s
law, Faraday’s law, and electric circuits. In México we studied the electrical circuits in series and in parallel and Ohm’s law with a Prototype constructed by the students. In both cases, we clearly appreciate the advantage of using the methodology used by Sokoloff et al. [7, 8, 9, 10, 11]. The advantage can be checked from the graphs of ICC for the items of the respective tests applied in each case, the probabilities to get a correct answer are in general better for Active Learning of Physics than for Traditional Learning.

The intentions of this work were to show examples of the use of two educational methodologies applied to Latin countries, and how these methodologies can support students of physics, particularly those who study topics related to the Theory of Special Relativity and Electrical Circuits, to improve their learning in those topics of study. We have used traditional methods to measure student progress. These methods include the Hake-Dellwo [22, 23], Student’s t test, and the easiness parameters, that come in the Rasch model [16]. We also have used graphical methods when we compare the ICC [17], of each item of the applied test.

Both Peer Instruction (PI) and Active Learning of Physics have shown clear advantages in the learning of students if we compare them with the methodology of traditional teaching. However, from the results obtained in this work, we can say that traditional teaching methods also have their own advantages in teaching the physics topics that we have dealt with in this work.

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