Experimental Activities with Bicycle at Circular Movement Learning: An Investigative Oriented Laboratory Good Experience with a Didatical Sequence

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Abstract: ***The implementations of practical activities in general are limited by the lack of support didactical material and laboratories. The present work shows a proposal to use practical investigative activities for teaching circular movement, using as experimental device the bicycle. The approach was based on meaningful learning, zone of immediate development, and levels of autonomy. Theoretical instructional materials, with a sequence of three scripts were proposed. We reported the use of the proposed material, and an objective questionnaire, validated using the Cronbach alpha statistical coefficient and subsequently, the Wilcoxon signs test was applied to the students' scores showing its effectiveness.***

Keywords: Investigative Oriented Laboratory, Levels of Autonomy, Meaningful Learning, Circular Movement, Immediate Development Zone

1. Introduction

Much has been written about the importance of experiments in physical education activities, but several problems arises and not allows this practice in Brazilian schools, especially in high school level as shown by Gaspar (Gaspar, 2014).

In some cases, due to the high relation (content/number of classes), the ex- perimental activities studies, despite their importance, are secondary or even, to take better advantage of the time available in the explanation of concepts and resolution of fixing exercises (Gaspar, 2014).

We and other authors identify the following tasks as pecursors for an investigation: Which one are the causes for that: i) lack of didactical material; ii) lack of correct environment to enroll the activities; iii) lack of time for preparing the use of that kind of experimental class.

It is well known that throughout history there have been concentrated efforts seeking to organize pedagogical practices experiments in physics teach- ing, such as the British program (The Nuffield Physics Project), the American (Physical Science Study Committee, PSSC) and (Physics Teaching Project, PEF). As comments Gaspar (Gaspar, 2014), from the pedagogical point of view, these programs and in particular the one used in Brazil throughout the years, was not successful due to the constructivist methodology used.

Thus, there is huge gap of pedagogical interventions that efficiently incorporates into the routine of learners at high school (or in the basic education) the use of experimental activities.

Another factor is that, in experimental practice, independent of the teaching method intended by the teacher, nullifying the student passivity is one of the main tasks for teachers in the process of learning, as comments by (Borges, 2002).

More specifically, we can cast at the circular movement content, the over- coming of at least three of the limitation factors cited by (Gaspar, 2014) deployment of experimental practices for the teaching of physics in schools: lack of material and equipment, lack of place for the realization of the experiments and lack of time to prepare the activities. We developed a support material that can assist the teacher in the experimental practices of circular movement content using as main device/laboratory as a bicycle in order to minimize such limiting factors.

To determine the psychological, pedagogical and theoretical physics basis to design the support material performed a Theoretical Review that is described in the next section.

2. Theoretical Basis

Considering that, educational system based on traditional practices can lead to students in different situations during their academic life to learn something which does not interest them or does not have direct daily application. We designed the support material based on the theory of meaningful learning, elaborated by Ausubel (Moreira, 1999), according to what the significance of the studied object for the student is part of the main objectives of the learning process, endorsing what we believe.

Another important perspective invoked by us during the conceptualization of the didactical material and intervention, and is preeminent at physics learning as reported by (Gaspar, 2014), and supported by Vygotsky's theory, is the student interaction with a more intellectually capable individual, which led to stimulation of the so-called Immediate Development Zone (IDZ), which among other practices recommends (Gaspar, 2014) knowledge and respect, by the teacher, at the student's cognitive level to teach any content.

Even if, for the teacher, the student's IDZ on the subject in question is below the level required to learn certain content, this is not something that should despair the teacher, since it can be expanded by the teaching of content and/or cooperation, while developing ideas, with someone who dominates this content, whom Vigotsky calls "a more able" or "more capable" individual. That interaction condition can be mediated from the teacher to a classmate, with whom in the most times the student has greater freedom of social interaction, hence the importance of the use of team work as a proposal for students' cognitive development.

This interaction between apprentice and more capable partner is given by imitation. It is by imitation, for example, that we learn to speak as children. A good example of imitation within the teaching-learning process of physics is the solving exercises with students. In some cases, before determined exercise by the teacher, students do not even know how to start solve it. But after the resolution, they can imitate the method of resolution used by the teacher, thus managing to solve exercises of order of difficulty even higher than initially proposed. Each exercise solved by the student becomes "a new resolution algorithm installed in his mind, " so the IDZ, initially found by the teacher, is modified giving origin to an enlarged IDZ.

As reported before one of the main concerns of meaningful learning is the student's interest (Moreira, 1999). Based on what has been described above, we look for ways to motivate students to the learning of new contents, in this case the Circular Movement, using in experimental practices objects and activities of the student's daily life, showing that in addition to the formalism of a school evaluation such content also has day-by-day application and become essential in certain activities, such as driving a car.

Also, considering that the daily practices of the student influence the process learning, we propose here the pedagogical practice oriented in a form of scripts and a didactical sequence, making possible and more efficient the learning process based on the imitation of small problems which can be presented systematically to students.

This type of experimental approach fostered by didactical sequences has been used in the literature. We can cite as example the book (Carvalho, 2013), which brings a set of articles that discuss the use of experimental investigative practices and didactic sequences in science teaching. The results achieved by the works in literature point to an effective gain in student learning. Therefore, we can say that acting on the theme of Circular Movement at the level of basic education through this style of pedagogical practice is quite feasible.

In this scenario, we will present in this work scripts of experimental activities based on two types of teaching laboratories, the traditional laboratory, and the investigative oriented laboratory. According to (Borges, 2002) in the traditional laboratory: the student performs practical activities, involving observations and measurements, about phenomena previously determined by the teacher (Woolnough, 1991). In general, students work in small groups and follow the instructions of a script. The purpose of the practical activity may be to test a scientific law, to illustrate ideas and concepts learned in theories, "to discover or formulate a law about a specific phenomenon", "see in practice what happens in theory", or "learn to use some instrument or specific laboratory technique".

The objectives of this type of laboratory would be: i) Verify/prove laws and scientific theories: what is seen by many authors as something inefficient since the student, knowing where he should arrive, will concentrate its efforts to achieve the answer given by the theory; ii) Teach the scientific method: how- ever we should not expect students to scientific behavior before this proposal, after all they are not scientists; iii) Facilitate the learning and understanding of concepts: the teacher should be aware of this objective, since what an individual observes depends on knowledge.

So it is interesting in this type of practice to make use of pre and post tests/questionaries on the concept in question; iv) Teach practical skills: Skills such as using equipment, doing and assembling are part of this objective and are a interesting considering that students will hardly have the opportunity to learn this in another place but the school laboratory.

In the investigative laboratory like quote Borges referring to the ideas of Coll (Borges, 2002) it matters little whether this activity consists of manipulations observable or in mental operations that escape the observer; it does not matter also responds totally or partially to the student's initiative, or that has its origin in the teacher's incentives and proposals. What is essential is that of an activity whose organization and planning is the responsibility of the student.

In this type of laboratory, from a problem, it is intended that the students can organize a plan work, collect reliable data, interpret data, interact with teacher and colleagues, and learn different languages.

In the specific case of language, language is no longer becoming scientific as the group explains to the class the form to solve the problem.

In view of the dichotomy mentioned above that concerns the laboratory practices of teaching, Borges elaborated a table where he divided the laboratory practices in according to the freedom given by the teacher to the student in the fulfillment of the activity. In this scheme, the higher the level of research, the greater the freedom given by the teacher in the activity.

Table 1: Explanatory table on levels of research

Investigation Level	Problem	Procedures	Conclusions
Level 0	Given	Given	Not Given
Level 1	Given	Given	Not Given
Level 2	Given	Not Given	Not Given
Level 3	Not Given	Not Given	Not Given

We can say that levels 0 and 1 are working to the traditional laboratory. On the other hand, a level 2 and 3 are the investigative laboratory, and is seeking to reach those levels that we will introduce the idea of Sequence of Investigative Oriented Teaching (SIOT).

A SIOT is a sequence of activities planned from the interactionist point of view and material, on a certain content. In a SIOT, what is focused is the student ability to solve problems and to elaborate a plan work in collecting and interpreting data as well as improving language through teacher-student and student-student interactions.

As indicated by (Carvalho, 2010) the application of a SIOT can be di- vided into four steps: i) Stage of distribution of the experimental material and proposition of the problem by the teacher; In this step, the groups, the materials are delivered and the problem is proposed with due care not to deliver the response to students. Later, the teacher must make sure that all groups under- stood what should be done; ii) Resolution phase of the problem by the student. Here the important thing is for students to produce hypotheses that, when tested, will solution of the problem. This is the stage where mistakes happen and the group can discuss the construction of the solution. iii) Stage of systematization of group. In this, ensured that the groups ended the proposed work, the materials are collected to avoid jokes. The from here, the groups are undone and a debate begins between all the students and the teacher. In the debate the students should explain to others what they have done to solve the problem. iv) Writing and drawing. This is the stage of individual learning, here students should write and draw what they have learned in class in order to that writing and drawing complement the construction of knowledge that is initiated by the dialogue.

So, we made a SIOT that vivifies the ideas of Vigotsky/Ausubel in the lines described respectively by (Gaspar, 2014) and (Moreira, 1999).

In order to prepare the didactical kit, based on a SIOT, we start to analyze theoretically the concepts related to the Transmission Relation (TR) or transmission ratio within the content of Circular Movement, pointing to bottlenecks/ conceptual appropriations that are commonly used by books and do not match the physical reality of some systems, allowing thus creating a platform for anchoring a discussion that will be conducted about the theoretical approach of the subject in question by some books that are contained in the National Program Book Guide (PNLD-Brasil) (da Educação, Secretaria de Educaçao Básica Fundo Nacional de Desenvolvimento da Educação, 2014), besides other bibliographic sources that serve the same purpose and which are used in the researched education scenario.

Theoretical Analysis of Physics High School Didactical Books

As pointed out, the main objective of this work was the development of a support didactical for the teaching of circular movement that use as the main laboratory/device the bicycle. In this sense we believe that material should address content that are within the program presented by the textbook, so that the teacher can use books and the proposed support material together.

Thus, we developed an analysis of the contents concerning the subject Circular Movement addressed in three textbooks aimed at regular education. As the Brazilian public schools are the most affected by the lack of equipment/laboratories, we seek to direct our analysis to the textbooks that participated in the PNLD (da Educação Secretaria de Educação Básica Fundo Nacional de Desenvolvimento da Educação, 2014), however we will also ana- lyze a book that is widely used in private schools and Federal Institute's of Education, Science and Technology once application places of the product here developed.

Analyzing the books references (Yamamoto & Fuke, 2014; Filho & Toscano, 2014; Ramalho et al., 1975) it was easy to see the existence of a common structure of approach to the content Circular Movement between them. This structure usually begins with the approach to angular magnitudes (space angular velocity, and angular acceleration), always relating these to the linear quantities, then it is presented the definitions of the quantities Period and Frequency then following to the Circular Uniform Movement (CUM) content where there are equations of linear and angular motion, and then circular motion trans- missions, where the equation for transmission relations[1] and where the types of transmission of circular movement, its characteristics and particularities. We say "should" because only one book (Ramalho et al., 1975) of those analyzed in this work addressed such a topic. The following is a summary of the content of Accelerated Circular Movement (ACM), where the Rectilinear Accelerated Movement and Accelerated Circular Movement equations are related.

A weak point common to all the books analyzed is related to the circular motion transmission ratio equation as discussed in next subsection **2.2.** In all cases, it was used in the development of the equation an analysis made on the transmission system used on bicycles, the crown/chain system. However, the equation found relates to relationships based on Pulley/Flat Belt and Friction Discs.

Teaching of Circular Motion Transmission Ratio: Conceptual Difficulties

Circular Movement Transmission Ratio or Relation is a numerical ratio, usually expressed in a fraction format that allows us to find the difference of angular velocity and consequent reduction or increase of the torque between two trees[2] which are joined by a circular motion transmission.

The speed difference between the trees occurs due to the difference of the pulleys' radii or friction wheels, as well as the difference between the number of the gears teeth where they are used.

1) Transmission ratio for pulley/flat belt and friction-type systems
2) Axis capable of transmitting torque.

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Considering the scheme below - Figure1, R_a and n_1 as radius of drive pulley[3] and number of teeth of the driving gear respectively, we can say that:

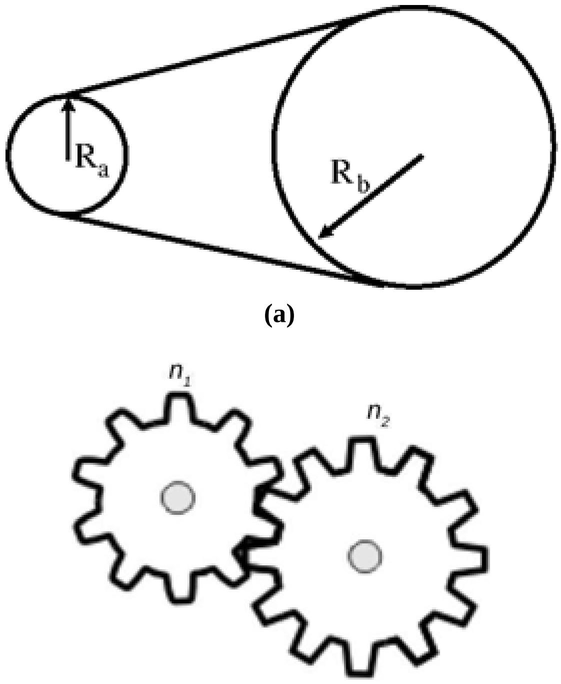

Figure 1: Schematic diagrams of (a) flat belt-coupled pulleys and (b) gearbox.

1) If R_a = R_b the Transmission Ratio R_a/R_b =1 that we read "one by one". In this case the two pulleys have the same angular velocity. The same occurs in cases where $n_1 = n_2$.
2) If Ra < Rb, for example R_a = 1 and R_b = 10, the relation becomes and we read "ten for one", in this case we say that there has been a reduction of the angular velocity at b. Angular velocity reductions are almost always associated with the need to the available torque in the set. The same is true in cases where $n_1 < n_2$.
3) If R_a > R_b, for example R_a = 10 and R_b = 2, the relationship becomes R_b/R_a = 2/10 and we read "two to ten", in this situation we say that there has been an increase in the angular velocity at b. The result in a decrease in the torque. The same also occurs in cases where $n_1 > n_2$.

The gear ratio can also be found or even projected with the use of the ratio of the transmission ratio. We will extract the transmission ratio equation by analyzing the following scheme of the Figure 2:

2 Pulley, wheels or gear that transmits the motion to the set under analysis.

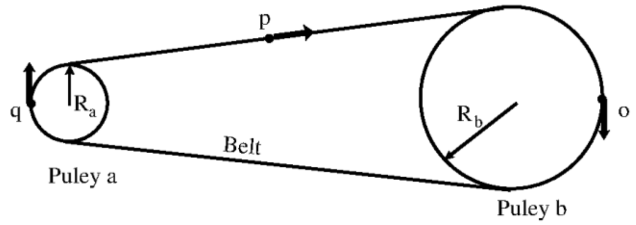

Figure 2: Schematic diagram of a relation of Transmission

The above scheme represents a pulley-belt drive ratio flat. In this scheme, assuming there is no slip between the belt and the pulley we can say that the linear velocity V_p of the point p on the belt is equal in modulus to the tangential velocities V_q and V_o of the point q and o also on the belt

Assuming that $V_q = \omega_a \cdot R_a$; $V_o = \omega_b \cdot R_b$ and $V_q = V_o$ we find:
$\omega_a \cdot R_a = \omega_b \cdot R_b$ (1)

On that way that $R_a/R_b = \omega_b / \omega_a$ = RT. (ω is the angular velocity and R is the pulley radius).

With the equation (1) we can design a transmission ration or relation (TR) that meet our needs for reducing or increasing the angular velocity in flat pulley-belt drives and friction wheels. However, we believe there is a mis- understanding in what concerns the application of equation (1).

The indisputable application in the ratios of the flat pulley and however, authors have associated the same equation with bikes, which are of the gear- chain type.

We reject the application of the equation (1) in the transmissions that have gears, since in everyday life, in the real case, how to analyze the transmission of a bicycle - see Figure 3, it is impossible to determine the effective radius of the gear since it has infinite rays from the base of the tooth to the peak.

Since it cannot determine the effective radius of the gear, that the equation

(1) is inadequate to find a relation in transmissions that make use of gears. Thus, another equation that characteristics of the gears developed.

Figure 3: Schematic diagram of the multiple radii of a single gear.

When analyzing the flat pulley-belt case with the aim of developing the equation

(1) we made use of tools to aid us in deduction. These tools were the points p, q, o and the velocities of these points, which associated with the radii and the angular velocities of the pulleys synthesized equation (1).

As explained above, we cannot rely on lightning when we deal with gears, however we can make use of the number of teeth, which in addition to being an integer is radius function in engineering calculations.

To find a gear ratio equation that meets the characteristics of the gears, we will use the following image - vide Figure4.

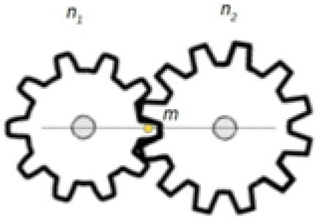

Figure 4: Schematic diagram of a coupled gear system with point of contact m.

If we analyze an imaginary point m fixed in the system is simultaneously located at the point of contact between the teeth of the gears as shown in 4, we can say that in a time unit the number of teeth N_1 of gear 1 which transpose m is

$N_1 = n_1 \cdot f_1$,

Been f_1 the gear 1 frequency and n_1 its number of teeth.

In the same way the number of teeth N_2 of gear 2 that transpose m is
$N_2 = n_2 \cdot f_2$.
f_2 being the frequency of gear 2 and n_2 his number of teeth.

Since at the point m each tooth of the gear 1 is attached to a tooth of the gear 2, we can say that for the same time unit $N_1 = N_2$.

In this way,
Hence,

$$n_1 \cdot f_1 = n_2 \cdot f_2 \qquad (2)$$
$$n_1/n_2 = f_2/f_1 \qquad (3)$$

Considering that $\omega_b = 2\,\pi\, f$ we conclude that
$n_1/n_2 = \omega_2/\omega_1$

n this sense, when we use the equation (4), we have gear ratio which is not based on the gearing the quantitative of teeth, which would be indicated for the analysis of the bicycle.

Now under consideration of the theoretical mathematical and physics anal- ysis, we discuss the investigative methodology used during the application of the proposed support material at two classes of students.

3. Methodology

The didactical material proposed, that can be seen at the supplementary material was made up as a support didactical kit for made by two parts, one for students, containing the theory for a circular kinematics course and transmission ratio. This support material is accompanied by a series of 3 experimental inves- tigative scripts for physics teaching that use as the main equipment a bicycle.

The methodology of application and evaluation of the didactical material during the research developed followed the steps:

1) Application of socio-economic questionnaire.
2) Elaboration and validation of multiple-choice questionnaire using Cronbach's alpha statistical coefficient.
3) Multiple-choice questionnaire pre-test application whose Circular Movement (CM) and transmission ratio (TR) contents.
4) Application of classes on CM and TR contents.
5) Application of the proposed experimental scripts on practical classes on the content.
6) Multi-choice questionnaire type test application whose Circular Movement (CM) and transmission ratio (TR) contents.
7) Statistical analysis of the results found in the previous and posttests, using the Wilcoxon sign poststest.
8) Analysis of the discourses and answers of the experimental practice scripts questions.

Now we discuss in more details each one of these steps.

Social Questionnaire

The application of a socio-economic questionnaire aims to support the results of the methodology proposed, in case there are occasional failures in the process of teaching learning by the students.

As students are socially active subjects and their social and economic con- texts can influence the teaching process learning, we decided to elaborate the socio-economic questionnaire in the hope of being able to explain some null or negative results that we can find at the final analysis of the didactical sequence.

The idea proposed above has great support in the literature as it shows us Pinto and Tenório (Pinto & Tenório, 2015), the evidence that the socio- economic level influence on student performance is confirmed by a large amount of research on the topic. Studies in Brazil show that the problem of income inequality is intrinsically related to the problem of low educational levels.

In this sense, we elaborated the following socio-economic questionnaire with the items that we believed were directly linked to student performance in the activities here proposals. Table 4, shown in Appendix A was used as social-cultural questionnaire.

Validation of the conceptual questionnaire via Cronbach Alfa coefficient

Aiming to know the students' cognitive structure, which participate in the application of the didactical material, with regard to the content of CM and TR, we applied the validated questionnaire as a previous-test. With this questionnaire also we intended to identify students who at some point had already had contact with the CM and TR content.

The questionnaire was created during the preparation of this work, based on high school textbooks. In order to validate it a statistical analysis of the reliability of this questionnaire was performed.

A group of 68 volunteers with different levels of knowledge was used: two second-year classes of high school, one with 26 students and the other with 34 students, a undergraduated physics students with 6 students and 2 teachers from the basic, technical and technological Brazilian carrier.

With the results obtained by this heterogeneous group we can statistically calculate a coefficient which is intended to determine the reliability of a questionnaire, the Cronbach's Alpha (α) (Bland & Altman, 1997).

Application of classes on CM and TR

Prior to the execution of each experimental script, the students went through lectures with duration of 50 minutes, on the topics covered in the scripts. This attitude aimed at encouraging the student interest in the subject, allow the acquisition of basic concepts and start development of an appropriate IDZ to carry out the road map in question.

Applying the Conceptual Post-Test Questionnaire

After the application of the didactical material, students were submitted to the post-test, a test that contained the same questions used in the previous-test. To prepare the post-test we used the entire structure of the pre-test, switching the positions of the alternatives in each question. As the students did not receive the pre-test after their correction, nor did they have access to the correct results, we could use the same questionnaire as a post-test to assess which had been appropriated by the students.

Statistical analysis of the results found in the previous- and post-tests using the Wilcoxon sign posts test

In order to evaluate the final result of the application of the didactical kit, the pre-test and post-test results were paired in a form table that could be compared.

A statistical test capable of analyzing paired data and informing the reliability of the result obtained in the comparison is the Signal Test of Wilcoxon (Triola, 2008). It is a nonparametric test that uses the scheme of posts to "test the null hypothesis that a population of data pairs have differences with medians equal to zero "as well as" test the hypothesis that a single population has the alleged median value.

We can say that, in the case in question, the null hypothesis tells us that there is no difference between the data compared, with any difference being coincidence, and in this hypothetical case the application of the product would not effectively learning.

4. Results

First of all, based on the theoretical review, the support material (didactical kit) was designed and implemented with the theoretical contents and the experimental scripts. The only remaining task was the conceptual questionnaire construction. In order to proposed, an original questionnaire was built with 16 multiple choice questions, one of them being a test question with the objective of verifying the attention and commitment of the research volunteers in the questionnaire solution. If the question was incorrectly answered by the volunteer its entire Questionnaire would be withdrawn from the statistical analysis because.

Each of the 16 questions had four (4) alternatives, but only one correct, except the test question, which had no alternative to be marked. Thus, if the test question had any option checked it would evidence inattention to the volunteer who was performing it. The issues raised in the test had mostly conceptual character. However, some also mathematical character. A heterogeneous group of people was used. Such a care was taken since "a sample of similar people may result in a low reliability questionnaire" (Freitas & de Arica, 2008) and "if we want to obtain measures with high reliability, we will need to base these measures in a sample of people who are heterogeneous in what respect to the concept being measured" (Freitas & de Arica, 2008).

On June 6, 2017 the questionnaire was applied to the class 2^0 year of the technical course in integrated to high school. This group counted on this with 26 students, who were clarified about the nature of the research and of its importance in physics teaching. Prior to the start of the students were instructed not to use electronic devices such as calculators and smartphones as well as not express some kind of reaction if any question "strange", they were also instructed not to comment another class of second year on the questionnaire, since this class also would perform the questionnaire on the same day. In the case of "strange" questions that did not know the answer, they were instructed to white, avoiding the "tip", that could cause a masking of the result of the questionnaire if the "tip" was correct.

The questionnaire was started at 9:28 A.M. The first delivery took place 13 minutes after the start, at 9:41 A.M., and your closing took place at 10:00 with the delivery of the last questionnaire.

The time chosen for the survey was the last class before the break, and we believe that the speed in delivering the questionnaire was due to possibility to leave the room after the end of the test and gain a few minutes to more than range.

On this group only 1 student marked the test question and its performance should be excluded from further analysis statistic.

At the same day the questionnaire was applied to the class 2^0 Year B of the technical course in integrated logistics to high school. This class counted on this day with 34 students.

The questionnaire was started at 10 : 00 A.M. and 46 delivery took place 14 minutes after the start, at 11 : 00 A.M., and its closure gave the 11 hours and 39 minutes with the delivery of the last questionnaire.

The time chosen for the test was the first class after the break, and we believe that the time chosen for the application of the questionnaire influenced in the time the students spent trying to answer the questions.

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Only 2 students signed the test question and its performance should be excluded from the analysis statistic.

The Cronbach's Alpha coefficient is always in the range [0, 1] and its minimum value for the reliability of a questionnaire is 0.70 ; below this value the internal consistency of the scale used is considered low. In contrast, the maxi- mum expected value is 0.90; above this value, it can be considered that there is redundancy or duplication, that is, several items are measuring exactly the same element as a construct.

Using the results of the questionnaires, excluding the participants that do not match the test question, we were able to set the following Table 5 - vide Appendix B.

As can be seen in Table 2, the coefficient found indicates low reliability (α = 0.664) so that the questionnaire under analysis cannot be used in full in the prospection of information regarding the circular movement learning. However, removing from the analysis the questions 13, 14 and 15 (resulting on the score Table 6 - vide Appendix B) we find α 0, 713, this value matches the reliability proposed by the literature, as shown in Table 3.

Table 2: Cronbach's Table

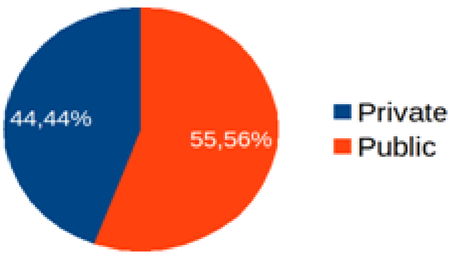
K	15
Sum of the variances of each question	2, 74
Total variance	7, 21
αCronbach	≈ 0, 664

Table 3: Calculation of Cronbach's Alpha excluding questions 13, 14 and 15 of the Original questionnaire of 16 questions.

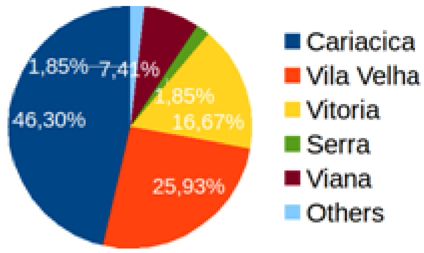
K	12
Sum of the variances of each question	≈ 2, 17
Total variance	≈ 6, 26
αCronbach	≈ 0, 713

After that the questionnaire used to prospect information about Circular Movement content in the classes where the didactical kit was used was calibrated and validated.

The next step was to apply and analyze the socio-economic questionnaires. We plot the graphs presented in Figure 5, prospected form the students considered throughout the research.



(a)



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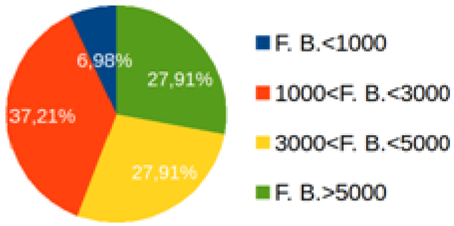

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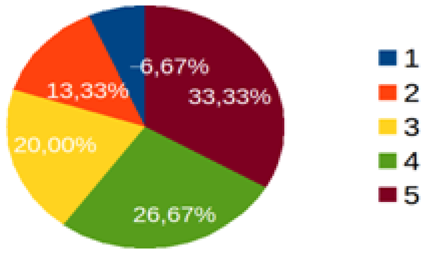

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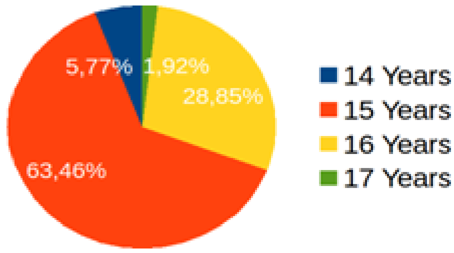

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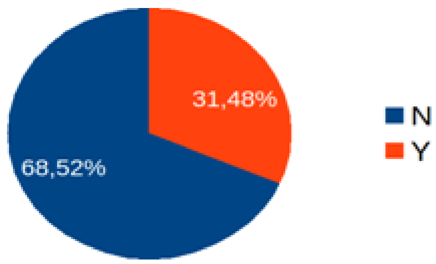

(f)

Figure 5: Graphs of student percentages for (a) distribution of the students analyzed by type of school administrative format (private or public), (b) student distribution analyzed by home city, (c) distribution of students analyzed by family budget (F.B.), (d) distribution of students the number of people living in the same student, (e) distribution of the analyzed students by age and (f) distribution of students analyzed for grade repetition.

Analyzing the above graphs we noticed that most of the students came from the city of Cariacica and almost totally the students reside in the metropolitan region of Vitoria city. We also note that regarding the type of school, private or public administration, the distribution is quite homogeneous, possibly due to the adopted affirmatives quotas for enrollment in the federal education network. With respect to income we see that the research was conducted with individuals at various levels of income, as expected due to distribution by type of school. We realize that the most students are at the age considered correct for the 1^0 year of high school, as well as have not attended this series.

In order to endorse the external influence analysis, we characterize the educational institution where the intervention was applied. It is located in the municipality of Cariacica and belongs to the federal education network. In this institution technical courses are integrated to the high school, and exists Graduate and postgraduate courses or entry into any of the education modalities, it is necessary to pass a selective process, being fifty percent of the vacancies allocated to the quota system. The classes are taught in air-conditioned rooms with computer for the teacher and projector multimedia. The institution also has didactic laboratories in the areas of computer science, physics, chemistry, biology, electrical, electronics, mechanics and hydraulic and pneumatic. It has a large library, sports gym, canteen, covered patio, emergency room care, psychological ser- vices and social service.

Now, considering that the didactical kit as shown in supplementary mate- rial, was used the students performance was measured via application of the two questionnaires, the previous-test and the post-test. The score table 7 and 8 are shown in Appendix C.

In Tables 7 and 8 were only considered students who completed at least half of the proposed activities (Experimental practices and fill in the Report) during the application of the didactical material. As noted, most students improved their performance in the post-test, which can be seen also analyzing the sum of the differences.

The Wilcoxon sign test was performed using the free program Wxmaxima, which returned the value of approximately T as 0.02 for class A and approximately 0.01 for class B. When we consider together the results of the classes, a value of $T \approx 0.0004$ which as can be seen in the Wilcoxon (Triola, 2008) tables, are values that confirm the efficiency of the methodology performed, that is, under T = 0.05.
Another result that allows us infer the efficiencies of the proposed didactical kit is the student's discourse. After the practical activities they were asked to prepare a report. This report could be written in a continuous form or in topic format, was necessary only that the following questions were answered:

- What was done by the team?
- How was it done?
- Where did I cooperate with the team?
- What did I learn?
- What do I find out from practice? Justify.

The first and second items of the questionnaire were to find out who was "really participating" in the activity, and those who were only accompanying the work of colleagues would not be able to argue about the actions of the group.

The third question was to investigate the student's level of participation in the activities of the group.

The fourth question was to determine if the student had concepts dis- cussed in the classroom and which should be consolidated during the practical activities

The fifth question, however, was only to what students thought about activities in the proposed by this work.

As for the learning proposed in this paper, we highlight some fragments of from the reports prepared by the students:

"I learned how to calculate the frequency in the circular motion. I learned to degree, degree and radian. A complete lap has in degrees: 360^0; in degree: 400; and in radian: 2π. I learned that it is a period, which is the time for the occurrence of a repetition, in the case the time of a return."

"In order to determine the angular velocity of the wheel, we calculate the period and we divide the angle of the wheel by the period."

"We measure the radius of the crown (motive), and the ratchet (moved),

"I learned how to calculate the frequency in the circular motion. I learned to degree, degree and radian. A complete lap has in degrees: 360º; in degree: 400; and in radian: 2 π. I learned that it is a period, which is the time for the occurrence of a repetition, in the case the time of a return."

"In order to determine the angular velocity of the wheel, we calculate the period and we divide the angle of the wheel by the period."

"We measure the radius of the crown (motive), and the ratchet (moved), and with the formula R_{mv}/R_{mt} we try to find the transmission relation that resulted in 0.5, but then the teacher taught us that there is no way to the exact radius of a sprocket, which is the case of the crown and ratchet, was not correct, then we would have to use another method, which teacher introduced us, we have $\omega_{mt}/\ \omega_{mv}$ = TR, substituting according to the formula $\omega = \Delta q/\ \Delta$ t, we have that $\Delta q_{mt}/\ \Delta\ t_{mt}\ \Delta\ t_{mv}/\ \Delta\ q_{mv}$ -> TR Using this formula we found that in fact the transmission ratio was 0.48 and not 0.5.

Analyzing fragments like these and taking into account that these reports were made after class and not during, we can say that there was the appropriation of concepts addressed in the content of circular movement such as angular space, period, frequency, angular velocity, and streaming.

Concerning the fifth questioning ``What did I find out of practice?" we exemplify the following fragments:

"I found the practice interesting because it puts us in practice what we have learned in theory. This makes the class more interesting, although at first, I was lost. But I got it later. understand what was being done with the help of teacher and friends."

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"I found it interesting because we usually get formulas and simply, we apply some values already provided and in this lesson we find values and we observe the actual application of the content."

"I found it very interesting, it helps a lot in the understanding of the subject, but this practice demanded a little more from us. " - Placement of a student to respect of the third report.

Reading these reports, and others, we noticed that students had a good acceptance to the teaching practices proposed in this work. We also note that the students realized the importance of practical activities. From the students' point of view the practical class left the subject more interesting, requiring the application of knowledge and demanding interaction with the teacher and colleagues. As proposed and intended by the prepared didactical kit.

5. Conclusion Remarks

In this paper we try to tackle three difficulties pointed out by physics teachers at the implantation of experimental activities on physics teaching. i) lack of equipment to carry out such activities: To solve this difficulty we seek to use an equipment that was part of the everyday life of the students and which did not need to be purchased - bicycle; ii) the lack of appropriate places, laboratories, to carry out the activities: This problem was, in our view, automatically suppressed when we choose the bicycle. because it was already being part of the daily life of the students, to be easy to move, does not produce noises or odors does not require a space special to be studied, just a few square meters of patio for such study; and iii) insufficient time necessary for the preparation of experimental activities of physics teaching: With the available instructional material and practical activities, as a didactical material we also believe that part of this difficulty encountered by the teachers can be reduced.
Although we use the scripts as explained above, we believe that each school, class and teacher have their particularities about the development of any content, and with circular movement would not be different, so we leave the responsibility with the teacher colleague make such changes as it deems necessary for the implementation of their classes.

The misunderstanding of conceptual points generally pointed at the text- books, we have taken on this work the freedom of develop an instructional material that deals with the content of circular movement as we believe that such content could be complemented with the use of the experimental activities scripts.

As presented in the fragments of the students discourse, the teaching methodology approach was well received by the students. We realized also showed that the students showed interest and, in some cases, even surprised by the methodology. Since they did not know physics classes with activities practices.

In addition to the acceptance by the students, the comparison of the previous- and post- conceptual questionaries showed a gain in students' performance in what concerns the proposed content, already the result of the Wilcoxon signs test shows by means of statistical procedure, that the result found by comparing the previous and post-tests was not a mere coincidence, that is, if we analyzed a sample; the final result of the comparison would accompany the found in the analysis already made.

In addition, this work shows us that the development of practical activities in physics teaching, at least in what concerns the content of circular movement need not be tied to the availability of laboratories and sophisticated equipment. The use of a simple object such as a bicycle in a small space as a classroom is shown as a good alternative for the implantation of experimental activities.

References

[1] Bland, J. M. & Altman, D. G. (1997). Statistics notes: Cronbach's alpha.BMJ, 314 (7080), 572.
[2] Borges, A. T. (2002). Novos rumos para o laboratório escolar de ciências. Caderno Brasileiro de Ensino de Física, 19 (3), 291–313
[3] Carvalho, A. M. P. d. (2010). Ensino de Física. Brasil, São Paulo: Cengage Learning, 1st edition.
[4] Carvalho, A. M. P. d. (2013). Ensino de ciências por investigação: condicões para implementação em sala de aula. Brasil, São Paulo: Cengage Learning, 1st edition.
[5] da Educação Secretaria de Educação Básica Fundo Nacional de Desenvolvimento da Educação, M. (2014). Guia de livros didáticos PNLD 2015 Ensino M´edio. Imprensa Nacional.
[6] Filho, A. G. & Toscano, C. (2014). Física - Interação e Tecnologia. LEYA.
[7] Freitas, A. L. & de Arica, G. (2008). A auto-avaliação: um modelo para avaliaçao de disciplinas curriculares, segundo a percepção do corpo discente. Revista Iberoamericana de Educación, (44).
[8] Gaspar, A. (2014). Atividades experimentais no ensino de física: uma nova visão baseada na teoria de Vigotski. Brasil, S˜ao Paulo: Livraria da F´ısica, 1st edition.
[9] Moreira, M. (1999). Teorias de aprendizagem. EPU.
[10] Pinto, J. C. A. & Tenório, R. M. (2015). A influência dos fatores socioe- conômicos no desempenho acadêmico dos estudantes de ensino médio in- tegrado do ifba/campus barreiras. Determinantes da Equidade no Ensino Superior.
[11] Ramalho, F., dos Santos, J., Ferraro, N., & de Toledo Soares, P. (1975). Os fundamentos da fisica. Moderna.
[12] Triola, M. (2008). Introdução à estatística. LTC.
[13] Woolnough, B. (1991). Pratical work at school: An analysis of current practice. Open University Press.
[14] Yamamoto, K. & Fuke, L. (2014). FíSICA PARA O ENSINO MEDIO, V.1: MECÂNICA. Saraiva - Didáticos.

a) Applied socio-economic questionnaire

Table 4 Representative table of the applied socio-economic questionnaire

Name:	School:
Date:	Class:
Question	Options
Original School was Public or Private	( ) Public
	( ) Private
City were the school belongs	( ) Cariacica
	( ) Vila Velha
	( ) Vitria
	( ) Serra
	( ) Viana
	( ) Outros:
Familiar economical Budget. (Do not need to be exactly)	( ) Lower than R$1000, 00
	( ) from R$1000, 00 toR$3000, 00
	( ) from R$3000, 00 to R$5000, 00
	( ) More than R$5000, 00
How many people live in your house with you?	( ) 1
	( ) 1
	( ) 2
	( ) 3
	( ) 4
	( ) 5
	( ) More:
Actual Age	( ) 14
	( ) 15
	( ) 16
	( ) 17
Have you coursed the actual Class?	( ) yes
	( ) no

b) Students Performance Scores - Validation of the conceptual questionnaire

Table 5: Table showing the overall performance of the groups evaluated

Question	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	Total
Student 1	1	0	1	0	0	0	0	0	1	0	0	0	1	1	0	5
Student 2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Student 3	1	1	0	1	0	1	1	0	0	0	0	1	0	0	0	7
Student 4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Student 5	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	5
Student 6	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2
Student 7	1	1	0	0	1	0	1	0	0	0	0	0	0	1	0	5
Student 8	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
Student 9	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	3
Student 10	1	1	0	1	0	0	1	1	0	0	1	1	1	1	0	9
Student 11	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	3
Student 13	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	3
Student 14	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Student 15	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	4
Student 16	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
Student 17	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	5
Student 18	1	1	0	0	0	0	1	0	0	1	1	0	1	1	1	8
Student 19	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	4
Student 20	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	4
Student 21	1	1	0	0	0	0	1	0	1	0	0	0	1	0	1	6
Student 22	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	4
Student 23	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	5
Student 24	0	0	1	1	0	0	1	0	0	0	0	0	0	1	1	5
Student 25	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Student 26	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Student 1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Student 2	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	4
Student 3	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	4
Student 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Student 5	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	5

Student 6	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	4
Student 7	1	1	0	0	0	0	0	0	0	0	1	0	1	1	1	6
Student 9	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	5
Student 10	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Student 11	1	1	0	0	0	0	1	0	0	0	0	1	1	0	1	6
Student 12	0	1	0	1	0	0	1	0	0	1	0	1	1	0	1	7
Student 13	1	0	0	1	0	0	1	0	0	0	1	0	1	0	0	5
Student 14	1	0	1	0	0	0	1	0	0	0	1	0	1	1	1	7
Student 15	1	0	0	1	0	0	1	0	0	0	0	0	1	0	1	5
Student 16	1	0	0	1	0	0	1	0	0	1	1	0	0	0	1	6
Student 17	1	1	1	0	0	0	1	1	0	1	1	1	1	0	1	10
Student 18	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	6
Student 19	1	1	1	0	0	0	1	0	0	1	1	0	0	0	1	7
Student 20	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	4
Student 21	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	6
Student 22	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	4
Student 23	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	3
Student 24	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1	7
Student 25	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	5
Student 26	1	1	0	1	0	0	1	0	0	0	1	0	1	0	1	7
Student 27	1	1	1	0	0	0	0	1	0	1	0	1	0	0	1	7
Student 28	1	1	1	0	0	0	1	0	0	0	1	0	1	0	1	7
Student 29	1	1	1	0	0	0	0	0	1	0	0	0	1	0	1	6
Student 30	1	1	1	0	0	0	1	1	0	0	0	1	0	0	1	7
Student 31	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Student 32	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	4
Student 34	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2
Student 1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	11
Student 2	1	1	0	1	0	1	0	1	1	1	1	0	0	0	1	9
Student 3	1	1	0	1	0	1	1	0	1	0	0	0	0	0	1	7
Student 4	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	5
Student 5	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	12
Student 6	1	1	1	1	0	0	1	1	1	0	0	0	1	0	1	9
Teacher 1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	14
Teacher 2	1	1	1	1	0	1	1	1	0	1	0	0	0	0	1	9

Table 6 Table showing the overall performance of the groups evaluated

Question	1	2	3	4	5	6	7	8	9	11	12	16	Total
Student 1	1	0	1	0	0	0	0	0	1	0	0	0	3
Student 2	1	0	0	0	0	0	0	0	0	0	0	1	2
Student 3	1	1	0	1	0	1	1	0	0	0	0	1	6
Student 4	0	0	0	1	0	0	0	0	0	0	0	1	2
Student 5	1	0	0	0	0	0	0	0	1	0	0	1	3
Student 6	0	0	0	0	0	0	1	0	0	0	0	0	1
Student 7	1	1	0	0	1	0	1	0	0	0	0	0	4
Student 8	0	0	0	0	0	0	0	1	0	1	0	0	2
Student 9	1	0	0	0	0	0	1	0	0	0	0	1	3
Student 10	1	1	0	1	0	0	1	1	0	0	1	0	6
Student 11	0	1	0	0	0	0	0	0	0	0	0	0	1
Student 13	0	0	0	0	0	0	0	0	0	0	0	1	1
Student 14	1	1	0	0	0	0	0	0	0	0	0	0	2
Student 15	1	1	0	0	0	0	1	0	0	0	0	0	3
Student 16	0	0	0	1	0	0	0	1	0	0	0	0	2
Student 17	1	1	0	0	0	0	1	0	0	0	0	1	4
Student 18	1	1	0	0	0	0	1	0	0	1	1	1	6
Student 19	0	0	0	1	0	0	0	1	0	0	0	0	2
Student 20	1	1	0	0	0	0	0	0	0	0	0	1	3
Student 21	1	1	0	0	0	0	1	0	1	0	0	1	5
Student 22	1	1	0	0	0	0	1	0	0	0	0	1	4
Student 23	1	1	0	0	0	0	1	1	0	0	0	1	5
Student 24	0	0	1	1	0	0	1	0	0	0	0	1	4
Student 25	1	0	0	1	0	0	0	0	0	0	0	0	2
Student 26	0	0	0	1	0	0	0	0	0	0	0	1	2
Student 1	0	0	0	0	0	0	1	1	0	0	0	0	2
Student 2	1	0	0	0	0	0	0	1	0	0	0	0	2
Student 3	0	0	1	1	0	0	1	0	0	0	0	0	3
Student 4	0	0	0	0	0	0	0	0	0	0	0	0	0

Student 5	1	1	0	1	0	0	0	0	0	0	0	0	3
Student 6	1	1	0	0	0	0	0	0	0	0	0	1	3
Student 7	1	1	0	0	0	0	0	0	0	0	1	1	4
Student 9	1	1	0	0	0	0	0	1	0	0	0	1	4
Student 10	1	0	0	0	0	0	0	0	0	0	1	0	2
Student 11	1	1	0	0	0	0	1	0	0	0	0	1	4
Student 12	0	1	0	1	0	0	1	0	0	1	0	1	5
Student 13	1	0	0	1	0	0	1	0	0	0	1	0	4
Student 14	1	0	1	0	0	0	1	0	0	0	1	1	5
Student 15	1	0	0	1	0	0	1	0	0	0	0	1	4
Student 16	1	0	0	1	0	0	1	0	0	1	1	1	6
Student 17	1	1	1	0	0	0	1	1	0	1	1	1	8
Student 18	0	0	0	0	0	0	1	1	1	1	1	1	6
Student 19	1	1	1	0	0	0	1	0	0	1	1	1	7
Student 20	1	0	0	1	0	0	0	0	1	0	0	1	4
Student 21	1	1	0	0	0	0	0	1	0	0	0	1	4
Student 22	1	0	0	0	0	0	1	0	0	0	0	1	3
Student 23	0	1	0	0	0	0	1	0	0	0	0	1	3
Student 24	1	0	0	1	0	0	1	1	0	0	1	1	6
Student 25	1	0	0	0	0	0	0	0	0	0	0	1	2
Student 26	1	1	0	1	0	0	1	0	0	0	1	1	6
Student 27	1	1	1	0	0	0	0	1	0	1	0	1	6
Student 28	1	1	1	0	0	0	1	0	0	0	1	1	6
Student 29	1	1	1	0	0	0	0	0	1	0	0	1	5
Student 30	1	1	1	0	0	0	1	1	0	0	0	1	6
Student 31	0	1	0	0	0	0	0	0	0	0	0	0	1
Student 32	1	1	0	0	0	0	1	0	0	0	0	1	4
Student 34	0	0	0	0	0	0	0	0	0	0	1	0	1
Student 1	1	1	1	1	1	1	1	1	1	1	0	1	11
Student 2	1	1	0	1	0	1	0	1	1	1	1	1	9
Student 3	1	1	0	1	0	1	1	0	1	0	0	1	7
Student 4	1	1	0	1	0	0	1	1	0	0	0	0	5
Student 5	1	1	1	1	1	0	1	1	1	1	1	1	11
Student 6	1	1	1	1	0	0	1	1	1	0	0	1	8
Teacher 1	1	1	1	1	0	1	1	1	1	1	1	1	11
Teacher 2	1	1	1	1	0	1	1	1	0	1	0	1	9

c) Students Performances Scores - Methodology Efficiency Measurements

Table 7: Worksheet with the results of the previous and post-tests of class A

Student	Pre-Questionnaire: 12	Post-Questionnaire: 12	Difference (Post-Pre)
1	6	5	-1
2	6	1	-5
3	5	7	2
4	4	8	4
5	1	6	5
6	1	9	8
7	5	4	-1
8	7	4	-3
9	3	4	1
10	6	9	3
11	6	9	3
12	4	7	3
13	7	5	-2
14	6	9	3
15	4	6	2
16	1	5	4
17	0	3	3
18	4	6	2
19	4	8	4
20	6	8	2
		Total sum of differences	37

Table 8 Worksheet with the results of the previous and post-tests of class B

Student	Pre-Questionnaire: 12	Post-Questionnaire: 12	Difference (Post-Pre)
1	6	7	1
2	2	4	2
3	8	11	3
4	4	6	2
5	5	7	2
6	4	5	1
7	2	4	2
8	2	9	7
9	3	3	0
1	3	7	4
11	4	3	-1
12	3	7	4
13	6	9	3
14	4	8	4
15	3	3	0
16	3	4	1
17	3	5	2
18	2	6	4
19	8	7	-1
20	3	9	6
21	6	6	0
22	3	3	0
		Total sum of differences	46

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