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Study of the Effect of the Demonstration Experiment on the Teaching of Direct Current Electrical Circuits to Second-Grade High School Students and Its Comparison With Traditional Teaching

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Abstract: It is widely known that electromagnetism is the most representative chapter of physics developed through historical experiments and certainly the most dominant teaching strategy in primary and secondary Education should focus on experiments, which is the milestone of the scientific methodology. This paper presents the results of the comparison between experiment teaching demonstration and traditional teaching model applied on high school students in the field of electrical circuits. The analysis of the results demonstrates the indisputably important role of experiment as a teaching tool, but also as a teaching component which can be used by the teachers to stimulate the interest of students by adopting a different approach from the traditional teacher-centered methodology.

Key words: effect, demonstration experiment, direct current electrical circuits, second-grade high school students

1. Introduction

The subject of electricity is introduced to students several times during their studies in primary and secondary education. In this field, important research has been conducted in recent years, on how students perceive ideas related to simple electrical circuits (Duit et al., 1985; Kotsis et al., 2011). The majority of existing research deals with the early stages of teaching very simple electrical circuits and especially with the models that students use to describe electricity (Duit, 1985; Shipstone et al., 1988). Less research has been done on more difficult concepts of electricity, such as voltage or the correlation of variables in more complex electrical circuits.

Several studies (Barbas, 2005, Kotsis et al., 2011) show that even after extensive teaching, students do not acquire sufficient knowledge of some basic characteristics of electrical circuits. A typical example is the fact that the vast majority of students focus only on the concept of electricity, rather than voltage, thus often confusing cause with effect. An important finding reported by several researchers is that students tend to think sequentially and locally about tackling problems in electrical circuits (Barbas, 2005). Those who make use of the sequential view, analyze the circuit in terms before and after, after the electric current "passes" through a specific point and always in the direction of the electric current (Duit & Rhoneck, 1985). On the other hand, students who use the

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local view, consider that the change in one point affects locally and not necessarily the whole circuit (Kuiper et al., 1985, Kotsis et al., 2011). The difficulty that students face seems to come from the inability to visualize phenomena and consequently to construct appropriate representations and mental shapes that will help them understand the basic structures and difficult concepts of electricity (Arnold & Miller, 1997). Finally, the knowledge of students about the area of electrical circuits at the end of their high school education is not satisfactory (Knight, 2006). These were the main reasons for choosing the study of this field.

Our general goal is to highlight the quality of treatment and analysis of electricity problems, in order for the student to acquire the ability to recognize the dynamics of systems and the interaction between variables. Many students who failed to explain qualitatively had previously successfully encountered more complex problems using extensive algebraic calculations (McDermott & Shaffer, 1992). There must therefore be a deep understanding of the natural variables before one can appreciate the mathematical equations and how they relate to each other. For the purpose of the research, the use of a written questionnaire was chosen, something that has been observed in the literature (Salih, 2005; Paraskevas P., 2007). Especially in our case, it was judged as the most appropriate tool in order to deal with a large sample of students, in a variety of physical situations. On the other hand, the strategy for the teaching followed, which is based on these ideas, was based on the demonstration experiment using worksheets.

2. Methodology — Research Design

2.1 The Questionnaire Before the Lesson (Pre-Test)

The research methodology was developed in order to monitor and record the evolution of students' conceptual change in the field of electrical circuits and the effectiveness of the traditional teaching model, compared to that of the demonstration experiment, as a learning process.

We initially asked the students of the schools that participated in the research to complete the questionnaire that had been constructed for this purpose. In this phase, the questionnaire was used as a diagnostic tool, in order to highlight the way students think about DC circuits and its concepts, before teaching the respective lessons (pre-test results).

2.2 Realization of the Courses During the Two Didactic Interventions

After the end of the first unit of the research, the teaching of the second chapter of the school departments began by the respective teachers. The second chapter refers to direct current and focuses on concepts of closed electrical circuits, which are the reference material (Physics BD High School of General Education). During this phase, all sections of the research schools were randomly divided into two groups of five each.

In the first group (control departments), the model of the teacher-centered approach to teaching was followed, while in the second group (laboratory departments), teaching was conducted by researchers, which was based on demonstration experiments. For this purpose, worksheets with appropriate questions were made.

2.3 The Questionnaire After the Lesson (Post and Post Delay Test)

After the completion of the courses during the two didactic interventions, the delivery of the same initial questionnaires followed in all the departments of the schools (laboratory departments and control departments). The delivery took place within a short period of time (up to five days), after the end of all courses. Our aim was to immediately record the evolution of students' knowledge, after the influence of the two teaching models (post-test results).

Our research ends with the re-final delivery of the questionnaires in all sections, after about two months, to determine if and to what extent the acquired knowledge (post-test results) changes for the sections that followed a different approach to teaching (post delay-test results).

3. Research Questionnaires — Experimental Worksheets

3.1 Quality of the Questionnaire

The measure for assessing the quality of the questionnaire is its difficulty. Difficulty is usually measured by finding the percentage of students who answered each question correctly. The questions vary in difficulty from 0 to 59, which is a reasonable range of values. An average difficulty value around 40 is usually considered ideal, although lower values are certainly not ruled out (Maloney et al., 2000). However, only a few questions (1a and 14) reach or exceed the 40 limits, which means that the overall estimated difficulty is clearly greater than the ideal one. Overall, the average of the correct answers of the students of all the departments reaches 17% (pre-test results).

3.2 Analysis of the Answers to the Questionnaire

A characteristic of the analysis method of students' answers is that it is not limited to their classification into right and wrong, but systematically analyzes the justifications of the answers, because we believe that this reveals the way students think and develop mental models, in order to make predictions about natural phenomena. It seems that students' mistakes are not accidental, but follow a common structure (Licht, 1991). The analysis was based on the approach, which requires the definition of the scientifically integrated answer and the grading of the explanations into specific categories (Driver & Erickson, 1983).

3.3 The Sample

Our research was carried out in three representative general high schools of the city of Ioannina and the written questionnaire of 18 questions was delivered in total to:

211 second grade students [2nd Lyceum (Four departments, total 79 students), 3rd Lyceum (Four departments, total 85 students) and Zosimaia school (Two departments, total 47 students)]

According to the curriculum, the students of the second grade (ages 16, 17 years old), had attended the teaching of electrical circuits two years ago, in the third grade of Gymnasium.

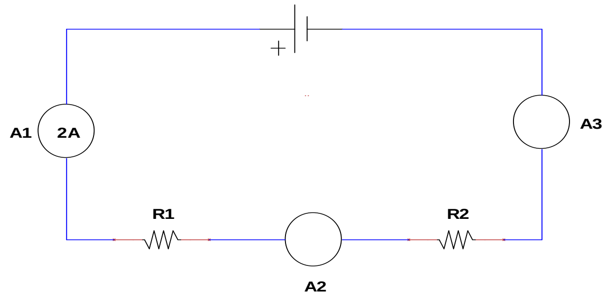
3.4 Development of the Questionnaire

From the study of the literature, a list was made of the concepts that students have and use to predict and interpret phenomena from the area of direct current circuits, the characteristics they attribute to them, as well as the reasoning they use. Based on this study, the questionnaire used was constructed.

None of the questions used are quantitative, i.e., no values are given in parameters to be answered with the help of mathematical relations. Here are some of the questions in the questionnaire.

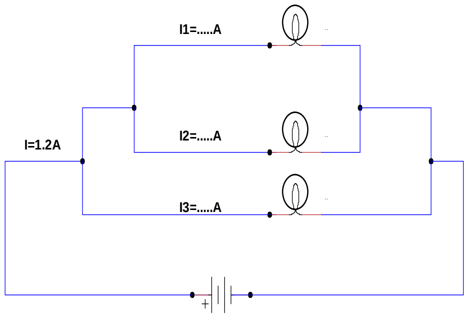
QUESTION 6

The following circuit includes a source, two resistors of different ohmic resistance and three ammeters. The reading of ammeter A1 is 2A. What do you think will be the indications of the other ammeters? (Note the indications inside the ammeters). Justify your answer.



QUESTION 7

In the circuit that follows all the lamps are the same. Fill in the figure the prices of electricity in the individual sectors. Justify your answer.



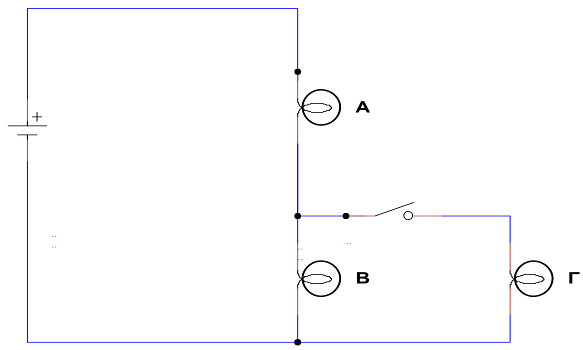
QUESTION 10

In the following circuit, which includes an ideal battery and a lamp, note the voltage values between the points given:

1 and 2: __________ V, 2 and 3: __________ V, 3 and 4: __________ V

QUESTION 13

The following circuit includes three identical lamps and an ideal battery (r = 0). Assume that the resistance of the switch is negligible. (Place an X in the corresponding box)



A) *How the brightness of lamp A changes when the switch is closed:*

I. *It remains fixed as it was with the switch open.*
II. *Its brightness increases.*

III. *Its brightness decreases.*

B) *When the switch is closed, then:*

I. *Lamps B and C illuminate the same.*

II. *Lamps A, B, C illuminate the same.*

III. *Lamps A and B shine the same.*

3.5 Experimental Worksheets

In the experimental worksheets, two experiments were carefully designed (one experiment is shown in the Appendix below) and question groups were set up to help students deal with misconceptions, as they emerged from pre-teaching questionnaires (pre-test results).

The overall analysis was based on guiding students in methodical tasks that require justification. Students first observe, then predict and record their views and finally analyze the experimental demonstrations with the help of the researcher. None of the worksheet questions require arithmetic. Each activity emphasizes a basic idea of direct current electrical circuits.

4. Results — Conclusions

4.1 Introduction

In order to be able to compare the two teaching interventions, a series of t-tests and ANOVA (unrelated analysis of variance) techniques were performed, in order to determine if there are statistically significant differences between the different groups of students. In this work, a correlated t-test was used to compare the results of the same section (pre-post-post delay), as well as an uncorrelated t-test (uncorrelated or unrelated t-test) to compare the different sections with each other.

All the quantitative data used come from the analysis of the results of the questionnaires. The statistical analysis of the research data was based on the change of the percentage of the correctly answered question, as it is expressed by the averages for each section and for each question. SPSS FOR WINDOWS VER was used for the quantitative processing of the results, as well as for the graphical representations. 10 and the MICROSOFT EXCEL program.

4.2 Statistical Analysis of Control Department Data

Initially we studied the results of the school departments, in which the course was conducted according to the model of traditional teaching.

Figure 1 below shows the percentage of improvement or not for each question at all stages of the research (pre, post, post delay). The listed percentages represent the average values in total for all five sections of the schools.

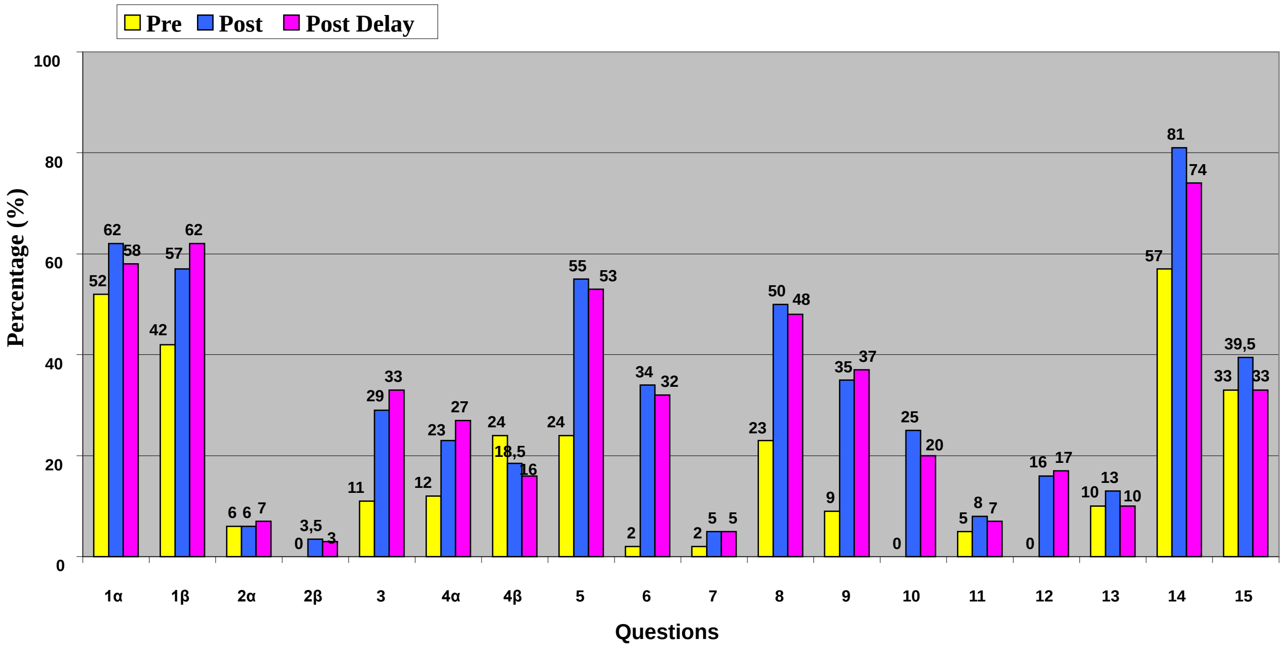


Figure 1 Percentage (%) of Correctly Answered Question Before, Immediately After and Much Later (Pre-Post-Post Delay) Traditional Teaching.

The average overall performance before traditional teaching was 17.3%, while the average overall performance immediately after traditional teaching was 31.1%. This difference (13.8%) also represents the overall average improvement in student performance immediately after teaching. On the other hand, the average overall performance much later in teaching, amounted to 30.1% and the corresponding average improvement reached 12.8%. From the test of the correlated t-test, it results that the mean of the pre-test ($M = 17.30$, $SD = 1.80$) and that of the post-test ($M = 31.14$, $SD = 8.76$) differ statistically significantly ($t = -3.34$, $df = 4$, $p = 0.029$, bilateral). Also statistically significant ($t = -4.48$, $df = 4$, $p = 0.011$, bilateral) differ the averages of pre-test and post delay-test ($M = 30.04$, S.D. = 5.81).

4.3 Statistical Analysis of the Data of the Laboratory Departments

Then we study the results of the school departments, in which the lesson was held with demonstration experiments. Figure 2 shows the percentage of improvement or not for each question in all phases of the research (pre, post, post delay). The listed percentages represent the average values in total for all five sections of the schools.

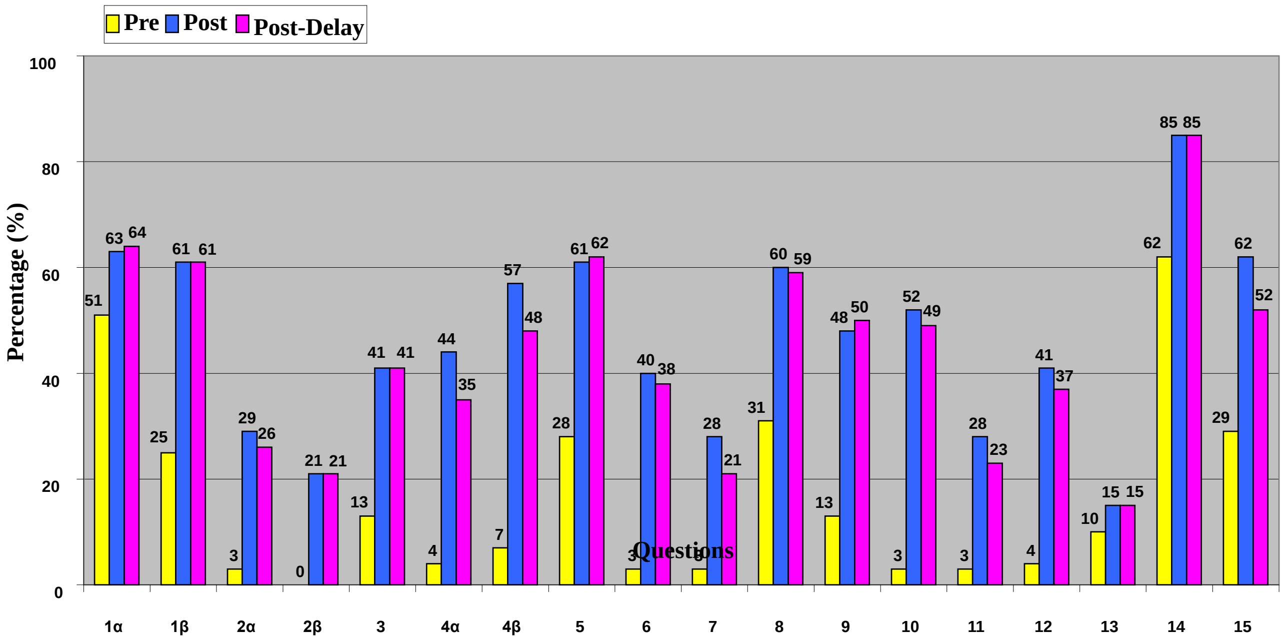


Figure 2 Percentage (%) of Correctly Answered Question Before, Immediately After And Much Later (Pre-Post-Post Delay) From Teaching With Demonstration Experiments

The average overall performance before teaching was 16.1%, while the average overall performance immediately after teaching with demonstration experiments reached 46.4%. This difference (30.2%) also represents the overall average improvement in student performance.

On the other hand, the average overall performance much later in teaching, amounted to 43.7% and the corresponding average improvement reached 27.5%. The correlated t-test-Paired Samples test shows that the mean of the pre-test (M = 16.06, SD = 2.07) and that of the post-test (M = 46, 38, SD = 10.68) differ statistically significantly (t = -7.14, df = 4, p = 0.002, bilateral). Also statistically significant (t = -5.86, df = 4, p = 0.004, bilateral) differ the averages of pre-test and post delay-test (M = 43.77, S.D. = 11.27).

4.4 Conclusions

Making a general assessment of the research findings, while checking our research hypotheses, we find that teaching with demonstration experiments, as an educational process, can be used to teach the subject of Physics in secondary education, since as the results show students seem to better understand the concepts and to acquire further knowledge, in relation to the traditional model. Such educational processes, although they do not involve the direct active participation of students, are recognized as contributing to better retention of attention, as well as to the immediacy of their communication with the teacher. In this way, the seamless presentation of the didactic contents is facilitated. Also, the clarity of the formulation of the teaching objectives by the researcher and the possible adaptation of the teaching to the level of the students, seems to have satisfied to a large extent the students and consequently their learning needs (Knight, 2006). Finally, it is worth emphasizing that in addition to any results, the desire was expressed by many students to continue the demonstration experiments (Barbas, 2005).

For this reason we believe that they can be used as a springboard and help significantly to make the Physics lesson friendlier, especially towards skeptical students.

We propose a gradual shift from the traditional description of knowledge to a teaching that will be pedagogically valid, using appropriate teaching techniques that will meet the modern educational needs of students. Such a change, of course, requires adjustments, not only by teachers, but also by curriculum designers. We hope our findings shed light on the construction of even more effective teaching strategies and learning processes that will fully meet the needs of a modern school, in a dynamically evolving society.

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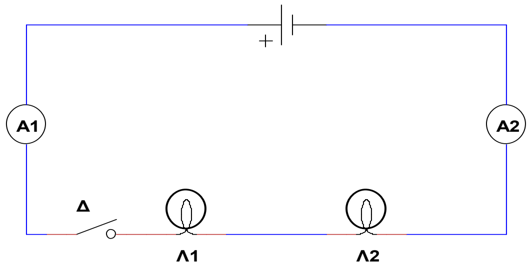
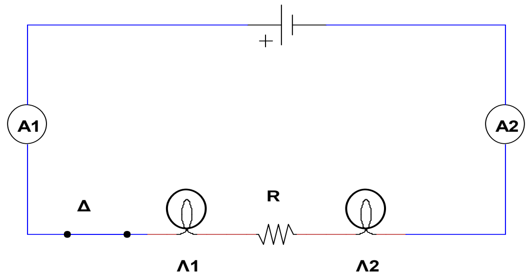
Annex Experimental Worksheet

The following circuit consists of a battery, a switch, two lamps (Λ1 and Λ2) and two ammeters (A1 and A2). Initially the switch is open, as shown in the figure. (For questions II, III and IV, the switch is off)

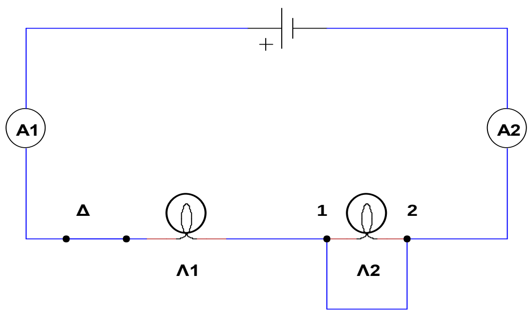


I. If I turn off the switch, what is your prediction for the ammeter readings and the brightness of the two lamps.
AMMETER INDICATIONS: A1 = A2, A1> A2, A1 <A2
LAMP LIGHTNESS: Λ1 = Λ2, Λ1> Λ2, Λ1 <Λ2, **Justify your answer.**

II. If I introduce an ohmic resistance R, (see figure below) between and in series with the two lamps, what do you think will happen to the ammeter readings and the brightness of the two lamps.



AMMETER INDICATORS: Increase, Decrease, do not change
WILL ALSO APPLY: A1 = A2, A1 > A2, A1 < A2
LAMP LIGHTING: Increase, Decrease, do not change
IT WILL ALSO APPLY: Λ1 = Λ2, Λ1 > Λ2, Λ1 < Λ2, **Justify your answer.**
III. If I unscrew and remove one of the two bulbs, what will happen to the ammeter readings: Increase, Decrease, Zero, **Justify your answer.**
IV. Remove the ohmic resistance. Connect points 1 and 2 with a wire (short the lamp 2), as shown in the figure below.



How do they change in this case:
Lamp brightness 1 (L1): Increases, Decreases, does not change
Justify your answer.
Battery Leakage Current: Increases, Decreases, does Not Change
Justify your answer.
The total resistance of the circuit: Increases, Decreases, does not change