PHET SIMULATIONS VS REAL EXPERIMENTS FOR BETTER UNDERSTANDING ELECTRICAL RESISTANCE

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ABSTRACT

In this research, we investigate the advantages and disadvantages of using real and virtual experiments in developing students' knowledge and skills. The investigation samples consist of 10th grade students of three gymnasiums in Macedonia. The students were divided into three groups: Real, Virtual and Traditional group. Real experiments were applied in the classes of the Real group, virtual experiments were applied in the classes of the Virtual group and traditional direct teaching was applied in the Traditional group. Students' task was to investigate how various ways of connecting electrical resistors influence the work of the electric circuit. The research shows that each of the approaches gives different contribution to the knowledge and understanding of the processes and concepts of teaching. Real experiments give contribution to the skills related to cooperation and teamwork, as well as better understanding of the phenomena. On the other hand, simulations give opportunity to the students to spend more time thinking about the results, phenomena and relations.

Keywords: *Virtual experiments, real experiments, conceptual knowledge, electrical resistance, high school students, electric circuit.*

1. INTRODUCTION

Students learn about simple circuits and connecting resistors in the primary school. In the gymnasium, they study circuits that are more complex. In order to solve problems with such circuits, beside lower level of knowledge and skills, students need higher order knowledge and skills. Misconceptions related to electric circuits are investigated by many researchers. Thus, there are reports with eleven possible misconceptions (Taşlıdere, Effect of Conceptual Change Oriented Instruction on Students' Conceptual Understanding and Decreasing Their Misconceptions in DC Electric Circuits, 2013). Other authors discover eight possible misconceptions (Koopmans, 2010). When compared these two lists, it can be seen that some of the authors find similarities between few misconceptions, so they put them in one group, while others find differences and divide them into more groups. For example, there are versions of a misconception, which say that the batteries possess electrons, or they produce electrons, or they store electrons (Koopmans, 2010).

Engelhardt and Beichner (Engelhardt & Beichner, 2004), discover that students think the voltage and resistance exist only when there is current, as well as confusion between electric current, its intensity, voltage and resistance. Possible source of these misconceptions can be the weak relation between electrostatics and electro kinetics.

Similar misconceptions are discovered by Periago and Bohigas, among students at engineering studies (Periago & Bohigas, 2005).

Understanding concepts related to electric circuits and influence of various teaching approaches are investigated by many authors (Dilber & Duzgun, 2008), (O'Dwyer, 2012), (Zavala, 2008), (Haertel & Divjak, 2010), (Nopparatjamjomras & Nopparatjamjomras), (Mallinckrodt, n.d.), (Flynn, 2011).

2. METHODS AND SAMPLES

2.1 The sample

The sample consists of second year students from three gymnasiums, in three different places in Republic of North Macedonia: Skopje, Tetovo and Valandovo. Two experimental groups and one control group are formed. The first experimental group consists of 59 students. The classes in this group were realized with real experiments and the group is called Real group. The second experimental group consists of 56 students. The classes were realized with computer simulations and the group is called Sim group. Traditional direct teaching was used in the Control group, which consists of 28 students. The students' knowledge in all three groups was measured with pre-test and post-test.

2.2 Students' activities

Lesson unit *"Resistors and their connection in electrical circuits"* was realized.

The students in the Real group were seperated into four groups, each of 5-6 students. As prerequisite experiments with directions were prepared. After completing the activities they presented the results and discussed them. The students in the Sim group used PhET simulation *Circuit-construction-kit-dc* (PhET, Circuit Construction Kit (DC Only), 2018). This simulation enabled performing the same experiments as the experiments in the Real group, which gave opportunity to make relevant comparison. After completing the activities, students in both groups discussed their results.

2.3 The test

To test students' pre knowledge and the knowledge acquired after the class, test was created with five questions, out of which four open ended questions and one multiple-choice question with one correct answer. In addition, the students had to explain their choice. The students were pretested in order to measure the pre knowledge and the acquired knowledge was post-tested. The same test was used for pre- and post-testing.

3. RESULTS

Taking into consideration that students in primary school have learned about the resistors and their connection to the electric circuits, to discover their previous knowledge, it was realized a pre-test, as well as after the realization of the unit "Resistor and their connection in the electrical circuits", the next hour, is realized post-test. The results of these tests are presented in the following text.

In order to see if students know where it is used the parallel combinations of resistors, the following question was required:

Question 1: There is a chandelier with more than one light bulb. One of the light bulbs burns up, but the rest of them continue lighting. How are they connected? Explain your answer.

The distribution of answers from the pre-test and post-test for all three groups are presented in the Table 1.

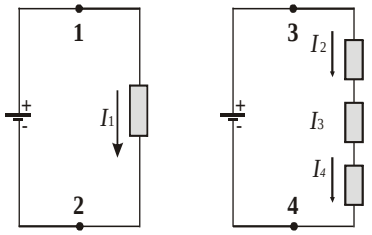
Table 1. *Distribution of answers to the question number 1 at the pre-test and post-test for all three groups*

	Pre-test (%)			Post-test (%)		
Group	Parallel	Series	No answer	Parallel	Series	No answer
Real	46	41	14	76	20	3
Sim	42	24	34	89	7	4
Control	40	33	27	61	14	25

In order to see whether the students are aware when resistors are connected in series flows the same current, and to apply the Ohm's law, the second question was asked:

Question 2: Two circuits are presented in the figure. The batteries in both circuits are with same characteristics and all four resistors have the same resistance.

a) Is the voltage between 1 and 2 bigger (U_{12}), lower or equal to the voltage between 3 and 4 (U_{34})? Explain your answer. Can you relate this case with any law or principle? If your answer is yes, then explain the law and the relation?
b) Order the currents I_1, I_2, I_3 and I_4, starting from greater to lesser. Explain your answer.



The distribution of answers from the pre-test and post-test for all three groups are presented in the Table 2.

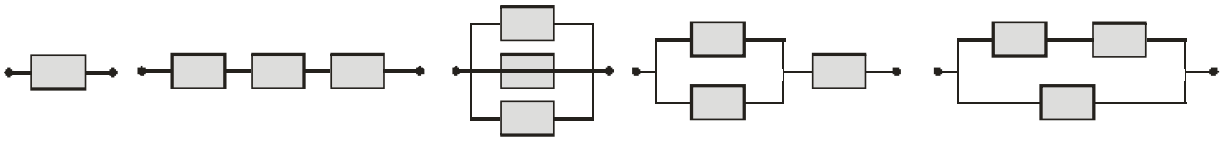
Table 2. *Distribution of answers to the question number 2 at the pre-test and post-test for all three groups*

a)	Pre-test (%)				Post-test (%)			
Group	Lower	Equal	Bigger	No answer	Lower	Equal	Bigger	No answer
Real	7	3	20	69	14	41	25	22
Sim	26	3	13	58	14	49	3	29
Control	7	13	3	77	29	14	7	50

b	Pre-test (%)			Post-test (%)		
Group	Correct	Incorrect	No answer	Correct	Incorrect	No answer
Real	3	71	25	64	17	19
Sim	19	31	50	68	13	20
Control	7	33	60	29	32	39

In order to see whether the students are able to apply the knowledge acquired during the teaching of a unit "*Resistor and their connection in the electrical circuits*", i.e. to apply in during solving concrete numerical problems, we have asked the following question:

Question 3: All resistors presented in the figure are with equal resistances. Sort the equivalent resistances starting with the smallest to biggest.



1 **2** **3** **4** **5**

The distribution of answers from the pretest and posttest for all three groups are presented in the Table 3.

Table 3. *Distribution of answers to the question number 3 at the pre-test and post-test for all three groups*

	Pre-test (%)			Post-test (%)		
Group	Correct	Incorrect	No answer	Correct	Incorrect	No answer
Real	0	61	39	71	10	19
Sim	8	52	40	54	24	22
Control	3	53	43	21	39	39

Similar to the previous question we have also asked the fourth question in which students should think about how to connect the resistors so they gain the required value. The question was as follows:

Question 4: You have resistors with the following resistances 10 Ω, 20 Ω and 30 Ω. You need resistor with resistance of 15 Ω. How will you connect the resistors in order to obtain the required resistance? Explain your answer.

The distribution of answers from the pre-test and post-test for all three groups are presented in the Table 4.

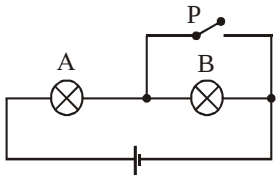
Table 4. *Distribution of answers to the question number 4 at the pre-test and post-test for all three groups*

	Pre-test (%)			Post-test (%)		
Group	Correct	Incorrect	No answer	Correct	Incorrect	No answer
Real	0	14	86	54	15	29
Sim	0	12	88	38	2	61
Control	0	10	90	18	4	79

The last question that we have asked was to find out whether students know how to apply the knowledge about series combination of resistors on one hand and the Ohm's law on the other. The question was as it follows:

Question 5: The light bulb A and B connected in the circuit light with equal intensities. When the switch P switches on, the light bulb A will light with a:

a) Bigger intensity
b) Lower intensity
c) Same intensity



The distribution of answers from the pre-test and post-test for all three groups are presented in the Table 5.

Table 5. *Distribution of answers to the question number 5 at the pre-test and post-test for all three groups*

	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	32	27	36	5	88	7	5	0
Sim	32	31	31	6	68	21	11	0
Control	30	17	40	13	43	32	25	0

4. DISCUSSION

The change between the response at the pre-test and the one at the post-test is very significant. However, if we consider that at the pretest there was not any student who gave explanation, unlike at the post-test, and then we can conclude that the change is very big.

The students in the Sim group had advantage in the conditions for working. They worked in couples, had opportunities to virtually connect the circuits and see the effect. The biggest disadvantage the Real group had was that the groups were too big (up to eight), which did not enable each student to take part equally in the activities.

Another advantage of the simulations is the good equipment with instruments and sensors. The computer is everyday toy for the students and when it is used for learning on regular base, then the children's psychological background changes. In this situation, students have fun, so learning becomes pleasure, so the results are better (Mork, 2005) (Oldham, 2003). They can repeat the activities any time they need. Students can change the task they have received and even go beyond the task, since the environment in which they work is safe. Finally, these activities can be incorporated in various educational games (Plowman, Stephen, Downey, & Sime, 2006). On the other hand, there are not such possibilities in the real experiments. They can be performed only in school during classes.

Of course, we must not forget the quality that the real experiments bring. This indicates that blended learning, by the old definition, which meant learning with various approaches give best results (Garrison & Kanuka, 2004).

Solving problems requires having minimum amount of information, knowledge and skills. When situation in supposed to be solved, besides the formulas students had to apply, they must think about the circuit they had to build. This means building more than one versions of the circuits, analyzing them, comparing, evaluating, and finally making conclusion in a form of solution. Of course, they have to check the solution. Some authors report better learning results with virtual experiments (Chini, Madsen, Gire, Rebello, & Puntambekar, 2012). We have to point out that these results do not include analysis of situations. On the other side, researches that include higher order thinking show advantage in favor of real experiments (Koray & Köksal, 2009), (Hofstein, 2004).

Choosing the destructor b) or c) at the fifth question, is in accordance with the misconception for local thinking, which says that every point in the circuit can be analyzed independently of other point in the circuit and the changes that go on in this point do not influence the behavior of the rest of the circuit.

After the class, the number of the students who chose these destructors significantly decreases. The relatively big percents of students who chose incorrect answer after the class is actually related to a mix of three possible misconceptions: misconception of parallel-connected consumer, misconception related to the electric current model of flowing water and misconception related to the model of attenuation. In order to come to the correct answer students have to understand the concept of short circuit and its influence on the behavior of the circuit. Further, they can use few different approaches, which come down to the same end. We believe that the approach that includes symbolic analysis will be difficult for some of the students and they could not come to the correct answer (Torigoe, 2012). The percent of the correct answer would probably increase if we add numbers to the quantities.

However, again the advantage of real experiments is shown.

5. CONCLUSION

The research shows that each of the approaches gives different contribution to the knowledge and understanding of the processes and concepts.

Real experiments give contribution to the skills related to cooperation and teamwork, as well as to better understanding of the phenomena. On the other hand, simulations give opportunity to the students to spend more time thinking about the results, phenomena and relations. One of the essential advantage that should be considered by the teachers, is the possibility to perform virtual experiments at home.

However, the two methods are complementary in developing students' knowledge and skills.

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