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Original scientific paper

REAL AND VIRTUAL EXPERIMENTS FOR BETTER UNDERSTANDING ELECTRICAL CAPACITY

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Abstract

This research paper investigates the influence of computer simulations (virtual experiments) on one hand and real experiments on the other hand on the conceptual understanding of electrical capacity. The target group was 10th grade high school students. The students were divided into three groups: Real, Virtual and Traditional group. Real experiments were included in the classes of the Real group, virtual experiments were included in the classes of the Virtual group and traditional direct teaching was used in the Traditional group. The research reveals that the virtual experiments' feature, to make the invisible things visible, influences the students' understanding in a positive way. On this basis, the students in the Virtual group have better answers and explanations from the ones in the Real group. The students in the real group compensate the lack of visualization with use of formulas, which in many time leads them to an incorrect answer. On the other hand, the research reveals that the students from the Real group can apply the acquired knowledge better than the ones in the Virtual group. One of the most essential advantages must be deeply considered by the teachers, possibility to perform virtual experiments at home. However, the two methods are complementary in developing students' knowledge and skills.

Keywords*: Physics teaching, virtual experiments, real experiments, conceptual knowledge, electrical capacity, high school students.*

1. Introduction

Even physics students at the university level have problems in understanding capacitance [10]. Most often, the model they build is based on the mechanical reading of the formula, which includes the key quantities [9]. Thus, they are not able to apply this model in a real situation.

Demirci finds significant differences in prejudice and misconceptions between boys and girls [6]. Raduta finds that many misconceptions have their roots in the textbooks [17]. The influence of various teaching approaches on conceptual knowledge is investigated by many researchers [3, 4, 7, 12, 18].

Computer simulations are flexible and adaptive to the students' style of learning [16]. The key characteristics of the computer simulations – visualization, interactivity, context and effective use for calculations – are an effective help to the students in understanding abstract concepts of a certain area of physics [3,14]. This can be achieved only by following a set of principles for design and appearance [1-2].

As other researches, our research shows that experimental activities in science, particularly in physics, obtain more quality knowledge, but only if the experiment is structured in a way that enables students to discover the physical laws [4]. The process of creating research, its planning and the analysis of the results can keep the students in the higher-order thinking area i.e. analysis, synthesis, and evaluation. In this sense, we prepared such activities for the students.

2. Methods and sample

2.1 The sample

The sample consists of second year students from three gymnasiums, in three different places in the Republic of North Macedonia: Skopje, Tetovo, and Valandovo. Two experimental groups and one control group are formed. The first experimental group consists of 77 students. The classes in this group were conducted with real experiments and the group is called the *Real group*. The second experimental group consists of 82 students. The classes were conducted with computer simulations and the group is called the *Sim group*. Traditional direct teaching was used in the control group, which consists of 56 students. The students' knowledge in all three groups was measured with pre-test and post-test.

2.2 Students' activities

In the Lesson unit "Electrical capacity and capacitors" the students in the Real group were divided into four groups, each of 5-6 students. Previously experiments with directions were prepared. After completing the activities, they presented the results and discussed them.

Students in the Sim group were also divided into groups, each consisting of two students. They used the PhET simulation "Capacitor Lab" to perform their activities (PhET). They also presented their results and discussed them.

2.3 The test

To test students' pre-knowledge and the knowledge acquired after the class, it was created a test with seven questions, out of which six questions were open-ended and one multiple-choice question. 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. The results

To understand whether the concept of electrical capacity is clear to students, the following question was required:
Q1: Does an uncharged neutral object have electrical capacity? Explain your answer.

The distribution of students' answers to pre-test and post-test for all three groups is presented in Table 1.

Table 1. Distribution of answers to the question number 1

	Pre-test (%)			Post-test (%)		
Group	Yes	No	No answer	Yes	No	No answer
Real	47	48	4	84	10	6
Sim	44	45	11	82	18	0
Control	32	66	2	52	44	4

To examine the understanding of the influence of electrostatic induction in changing the electrical capacity of a charged body, the second question was required:

Q2: If one brings a hand close to the charged electroscope, the deflection of the indicator gets lower. Explain this phenomenon.

The distribution of answers to question number 2 at the pretest and posttest for all three groups is presented in Table 2.

Table 2. Distribution of answers to the question number 2

	Pre-test (%)			Post-test (%)		
Group	Correct	Incorrect	No answer	Correct	Incorrect	No answer
Real	0	48	52	35	40	25
Sim	0	52	48	26	30	44
Control	0	54	46	11	78	11

In order to see if the students know what depends on the electrical capacities of the capacitors, the third question was asked, which states:

Q3: Capacitance of a capacitor is:

a) Quantity, which a capacitor has when charged and is proportional to the charge of the plates and inverse proportional do the voltage,
b) Quantity, which a capacitor has when charged and is proportional to the voltage and inverse proportional does the charge of the plates,
c) Quantity, which is characteristic of a capacitor and depends on the material between the plates, the area of the plates' surface and the distance between them,
d) Quantity, which is characteristic of a capacitor, and depends on the material of the plates, the area of the plates' surface and the length of the plates.

The distribution of answers to question number 3 at the pretest and posttest for all three groups are presented in the Table 3.

Table 3. Distribution of answers to the question number 3

	Pre-test (%)					Post-test (%)				
Group	A	B	C	D	No answer	A	B	C	D	No answer
Real	47	17	26	9	0	22	6	69	1	1
Sim	40	25	32	2	0	19	2	68	11	0
Control	54	27	12	8	0	33	19	41	7	0

In order to see if it is clear to students that when changing the potential difference in the capacitor's plates, changes the electric charge rather than the capacity of capacitors, the fourth question was asked:

Q4: How the electric charge will change if the potential difference between the plates of a capacitor:

a) doubles, b) triples c) halves

The distribution of answers to the question number 4 at the pretest and posttest for all three groups are presented in Table 4.

Table 4. Distribution of answers to the question number 4

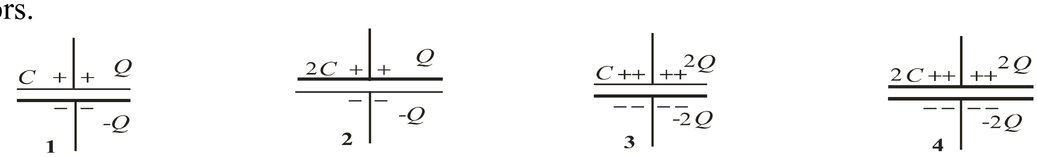
a)	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	14	0	16	71	79	0	6	14
Sim	16	6	13	66	70	2	4	25
Control	12	0	8	81	56	0	7	37
A) Increases two times; B) does not change; C) decrease two times								

b)	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	15	0	16	69	74	0	8	18
Sim	20	5	11	64	72	2	4	23
Control	15	0	8	77	56	0	11	33
A) Increases three times; B) does not change; C) decrease three times								

c)	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	17	0	12	72	8	0	74	18
Sim	16	7	8	69	5	2	65	28
Control	23	0	8	69	7	0	59	33
A) Increases two times; B) does not change; C) decrease two times								

Similar to the previous question, the fifth question was asked from the images that were listed and the labels that were enrolled, where students had to order by size the potential differences that appear in all four cases. The question was:

Q5: Order by size, starting from greater to less, the potential difference in the following four capacitors.



The distribution of answers to the question number 5 at the pretest and posttest for all three groups are presented in the Table 5.

Table 5. Distribution of answers to the question number 5

	Pre-test (%)			Post-test (%)		
Group	Correct	Incorrect	No answer	Correct	Incorrect	No answer
Real	9	56	36	57	27	16
Sim	10	33	56	53	19	28
Control	8	42	50	11	67	22

To see if the students know that the capacity of a capacitor does not depend on the voltage that was introduced on its plates, similar to the fourth question, the next question was required as it follows:

Q6: What will happen with the capacitance of a capacitor if the potential difference triples?

The distribution of answers to the question number 6 at the pretest and posttest for all three groups are presented in the Table 6.

Table 6. Distribution of answers to the question number 6

a)	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	7	0	28	64	3	52	29	16
Sim	14	0	25	61	11	63	9	18
Control	12	0	4	85	44	0	22	33
A) Increases three times; B) does not change; C) decrease three times								

In order to see if students know that the capacitance of capacitors depends on the material between the plates, the last question was required:

Q7: What will happen with the capacitance of the capacitor if a dielectric is placed between the plates? Explain your answer.

The distribution of answers to the question number 7 at the pretest and posttest for all three groups are presented in the Table 7.

Table 7. Distribution of answers to the question number 7

a)	Pre-test (%)				Post-test (%)			
Group	A	B	C	No answer	A	B	C	No answer
Real	14	1	5	80	71	3	1	25
Sim	16	2	5	77	67	7	5	21
Control	12	19	0	69	33	0	11	56
A) It increases; B) Does not change; C) It decrease								

4. Discussion

Unlike at the pre-test, at the post-test, most of the students in the experimental groups have given the correct explanation. It was not mentioned in any of the three groups that objects have capacity whether or not charged. However, it is obvious that the activities in the experimental groups initiated deeper thinking, so the students could come to the correct conclusion.

Although the Sim group used very powerful simulation, visualizing all necessary quantities and processes, the results of the Sim and Real group are very similar. This can be proof of the power that real experiment has in theinitiating thought process.

The students in the Real group had the opportunity to see the demonstration, which is similar to the situation in the second question. Thus, they have a better response from the students in the Sim group. However, the students in the Sim group had simulation, which enabled them to change all possible quantities and see all relations between them, which they used later to analyze and to come to a correct answer.

The results from the test reveal the misconception, which says that the capacitor possesses capacitance only when charged. The distracter b) at the third question reveals the problem with misusing formulas when explaining concepts and phenomena. The students, mostly in the control group, in their answers, incorrectly refer to the formula $C=Q/U$ and pointed out that, when $Q = 0$, then $C= 0$! They have learned the formula about the relation between capacitance, voltage and charge in the primary school, but they have not understood it and used it incorrectly. Such problems are reported by other authors also [9].

The fifth question shows the biggest difference between the experimental groups and the control one. The responses at the pre-test are very similar, which enables the same starting level for all groups. This result is in accordance with the other visual questions, where students were supposed to answer based on a drawing or were supposed to answer in a form of drawing. In all these cases, the students from the control group were with the worst response. In these cases, the higher-order thinking comes up to the fore. The students have to analyze the situation and they have to compare, apply and evaluate the information collected from the picture and finally come to a conclusion.

The advantage of the activities in the experimental groups over the traditional direct teaching is obvious in the responses to the sixth question. Although in the primary school physics textbook, the capacitance is mentioned as a constant of proportionality, no student gave the correct answer to this question. In the secondary school physics textbook, the capacitance is introduced through an experiment. At the post-test, there is no correct answer in the control group, yet. Whether they used the correct or incorrect formula, the answer is still incorrect. On the other hand, 52% of the students from the Real group and 63% of the students from the Sim group gave the correct answer. The advantage of the Sim group does not surprise, because the simulation enabled them "to see" the electrons in the simulation and all changes that went on in the capacitors.

The seventh question is again related to the same experiment in the Real group and the same simulation in the Sim group. Although the students in the Sim group used the same simulation and it was expected to be in advantage again, it did not happen. The students' task was to change the material between the plates and to measure the capacitance. It means that they did not change the value of the dielectric constant continuously. They have noticed that there was a change, but, did not notice the relation. Very often, when there is the relation between a certain quantity and characteristics of the material, the students say, that "…the certain quantity is directly proportional to the material…" or something similar, without paying attention that it is relation between two quantities and between quantity and material. In the meantime, the simulation is upgraded with a possibility to change the value of the dielectric constant continuously, which enables the teachers to recreate the activities for the students.

5. Conclusions

This research shows that the activities performed in the experimental groups contributed much more in developing the thinking process and to the quality of the acquired knowledge, over the ones in the control group.

We can notice the advantage for the Real group almost in all answers. Among others, that can be a consequence of better communication between the students [20]. During the performing, the experiments students intensively discussed, pursuing each other, explaining their thoughts. Thus, learning became dynamic, fun, informal and what is very important, peer instruction becomes very intense [13]. The subgroups in the Sim Group usually consisted of two students. Additionally, students are used to isolating themselves while working with a computer. In that case, most of the communication is between the student and the computer.

However, the advantages that virtual experiments bring cannot be neglected. Possibility for visualization gives its contribution to the key moments. Possibility to move the research laboratory at home is another big advantage of simulations over real experiments. Instead of giving to the student's problems to solve and questions to answer, which students do not like and have problems with this kind of home works [9], teachers can give home works for the students in the form of experimental investigation.

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