New Trends and Issues Proceedings on Humanities and Social Sciences

Volume 4, Issue 8, (2017) 32-39

ISSN:2547-8818
www.prosoc.eu

Selected paper of 8th World Conference on Learning, Teaching and Educational Leadership, (WCLTA 2017) 26-28 October 2017, Universidade Aberta, Lisbon, Portugal

Pre-service teacher's understanding levels of capacitors and instructors' predictions about the given responses

Ali Yildiz [a]*, Faculty Education of Kazim Karabekir, Ataturk University, 25240 Erzurum, Turkey

Suggested Citation:
Yildiz, A. (2017). Pre-service teacher's understanding levels of capacitors and instructors' predictions about the given responses. *New Trends and Issues Proceedings on Humanities and Social Sciences, 4*(8), 32–39. [Online]. Available from: www.prosoc.eu

Selection and peer review under responsibility of Prof. Dr. Jesus Garcia Laborda, University of Alcala, Spain.

Abstract

This study explores the understanding levels of pre-service teachers of the elementary school mathematics teacher education undergraduate program about capacitors that they learned in the compulsory Physics-2 course in the second year of the second term, and instructors' predictions about the teachers' responses. A total of 54 pre-service teachers participated in the study. The findings of the study reveal that 62.9% of the pre-service teachers did not know the function of a capacitor, 46.3% could not write any equations in connection with the capacitor and 57.4% could not explain any of the quantities in the formulas related to the capacitor. Instructors who taught Physics-2 at the undergraduate level were asked to predict the percentage rate of success of the answers the pre-service teachers gave about capacitors. The data reveal that the instructors were not sufficiently aware of pre-service teachers' knowledge of capacitors, although they taught them Physics-2 and evaluated them.

Keywords: Capacitors, pre-service teachers, instructors, views, predictions.

* ADDRESS FOR CORRESPONDENCE: **Ali Yildiz,** Faculty Education of Kazim Karabekir, Ataturk University, 25240 Erzurum, Turkey.
E-mail address: ayildiz@atauni.edu.tr / Tel.: +90-533-632-1860

1. Introduction

A capacitor is a device comprising two conductors separated by an insulating medium. Capacitors are circuit components that are used to store electrostatic potential energy or charge (Young & Freedman, 2009). Capacitors have many uses such as minimising voltage fluctuations in electrical circuits, finding channels/stations in radio and television devices, eliminating sparks in automotive ignition systems and storing energy in electronic flash units (Serway & Beichner, 2010 ; Young & Freedman, 2009). Moreover, with a large number of parallel connected capacitors, it is possible to release a high energy output in a very short period of time. The energy released is used in controlled nuclear fusion experiments (Young & Freedman, 2009). Capacitors that are used for research purposes have become important, and their uses in many different fields have become more diverse. When the geometry of capacitors is considered, they are of three types: parallel plate, cylindrical and spherical.

A parallel plate capacitor is the simplest type. It consists of two thin conducting areas *A*, which are parallel to each other and separated by a distance *d*. When the capacitor is charged, one of the plates of equal magnitude carries a positive charge (*+Q*) and the other carries a negative charge (*-Q*). When the charge of the capacitor is mentioned, the magnitude of the charge (*Q*) of one of the plates is considered (Halliday, Resnick & Walker, 2014, p. 657). A potential difference (*ΔV*) occurs due to the electrical charges stored between the plates in a capacitor. When the amount of charge *Q* stored in a capacitor is proportional to the potential difference between the plates, the capacitance, *C*, of the capacitor is calculated as $\left(C = \frac{Q}{\Delta V}\right)$. The capacitance is a measure of the amount of charge a capacitor can store, and this is determined by the kind of dielectric between the plates and by the capacitor geometry. The SI unit of capacitance is a farad; (1 farad = 1 coulomb per volt or 1*F* = 1 *C*/*V*). The capacitance *C* of a capacitor can be calculated as the ratio of the magnitude of the charge on either conductor to the magnitude of the potential difference between the conductors; however, the capacitance of a capacitor depends only on the dimension and shape of the conductors; and the type of insulating material between them (Young & Freedman, 2009, p. 816). Considering the last statement, if the vacuum between them is considered as the insulating material, the capacitance *C* of a parallel plate capacitor can be written as follows:

$$C = \epsilon_0 \frac{A}{d} \tag{1}$$

where ϵ_0 in the equation is known as permittivity of free space

$$(\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}) \tag{2}$$

When a bow is drawn, it stores energy called elastic potential energy. Similarly, in order to create a potential difference between the conducting plates of a capacitor, the plates must be charged with an electrical charge. Work is done in charging the capacitor. Electric potential energy is stored (*U*) to the same degree as the work done between the electric fields of the conducting plates of a capacitor. The energy stored is described using the below equation, in terms of the capacitance of a capacitor and the potential difference (Halliday *et al.,* 2014, p. 667; Serway & Beichner, 2010, p. 814; Young & Freedman, 2009, p. 824):

$$U = \frac{1}{2} C (\Delta V)^2 \tag{3}$$

When the capacitor is discharged, this stored energy is recovered as work done by electrical forces.

Studies (Altun, 2009; Celik, Pektas & Demirbas, 2012; Demirezen & Yagbasan, 2013; Osborne & Freyberg, 1995; Salar, Uzun, Karaman & Turgut, 2016; Sencar & Eryilmaz, 2004) reveal that students at all levels of education do not learn electricity topics included in science and physics curricula at the desired level. In the study, the ratio of correct answers to questions on capacitors given by 136 pre-service teachers studying physics teaching is significant (Salar *et al.,* 2016). The correct responses given by the pre-service teachers were as follows: only 40.9% of the participants answered the question about finding the charge of a capacitor by discharging the other capacitor in a mixed type of capacitor (capacitors both in series and parallel), 34.1% of them answered the question that asked the calculation of equivalent capacitance and total charge, 26.1% of them answered the question that examined whether the capacitance changes depend on the potential difference and 44.3% of them responded to the question that studied the change observed in the electrical charge stored by a capacitor depending on the potential difference.

Learning the basic concepts of capacitors, especially quantities and equations, correctly, effectively and adequately helps in understanding the subject of electricity much more easily as well as constructing the subject correctly and permanently in students' minds. Although capacitors are taught in the high school and at university, it is considered that the pre-service teachers' understanding of basic concepts, quantities and equations related to capacitors is not at the desired level. It is predicted that using the methods and techniques during the teaching of concepts, formulas and equations about capacitors will engage pre-service teachers' in thinking and provide them with opportunities for discussions that will facilitate and develop their understanding of concepts, formulas and equations and maximise their learning.

1.1. The purpose of the study

The purpose of this study is to explore the understanding levels of pre-service teachers studying in the Elementary School Mathematics Teacher Education Undergraduate Programme, about capacitors that they have learned as a compulsory topic in the Physics-2 course during the second term of the second year, and the instructors' predictions about the pre-service teachers' responses.

2. Method

A total of 54 pre-service teachers (43 females, 11 males) in their third year of studies in the undergraduate programme of Elementary Mathematics Teacher Education in the education faculty of a state university, and who took Physics-2 in the second term, participated in the study. The average age of participants was 21 (21.4) for females and 23 (22.7) for males. Based on the pre-service teachers' declaration of their letter grades in Physics-2, it was determined that 4 participants got AA, 8 pre-service teachers took BA, 9 of them got BB, 11 of them got CB and 2 received DD. The data of the study were gathered via an interview form consisting of four open-ended questions developed by the researcher in consultation with an expert. The pre-service teachers' responses and explanations to the questions in writing were read, examined and grouped according to their contents, similarities and associations. The responses, total number of the pre-service teachers as females and males, their percentages and the instructors' predictions of percentages for the given responses were tabulated. At the end of each table, necessary explanations about the data were made.

Of 54 pre-service teachers who expressed their knowledge of capacitors in writing, interviews were carried out individually with randomly chosen 7 pre-service teachers among those, who could spare the time and had volunteered. Moreover, after the open-ended questions were asked of the pre-service teachers, face-to-face interviews were carried out with five experienced instructors who taught Physics-2 in previous years and who would most probably continue to teach in the coming years. The instructors were asked to predict pre-service teachers' responses to the open-ended questions about capacitors, and the percentages of their responses to each question (6.0%, 10.0%, 20.0%). After calculating the arithmetic average of the percentages for each answer taken from the instructors, they were presented in the row including the relevant student response and in a different column in Table 1. No recording device was used during the interviews because it was considered that some participants would be disturbed by audio-video recording devices, or they would not consider them appropriate.

3. Findings

Figure 1

Question 1. In your opinion, what is the name of the circuit component shown with the symbol given in Figure 1?

Table 1. Pre-service teachers' responses for the name of the symbol given in the circuit component

Written answers	Female	Male	Total	%	Predictions of instructors (%)
Capacitor	41	9	50	92.6	75.0
Other answers (capacitance, voltmeter)	1	2	3	5.6	1.0
Generator, battery	-	-	-	-	13.0
No answer	1	-	1	1.9	11.0
Total	43	11	54	100	100

It is a positive condition that without mixing capacitors with other circuit components like a battery and switch, pre-service teachers responded correctly at a high percentage rate (92.6%) by looking at the symbol of a capacitor. Using documents that presented the symbols of three circuit components together in different colors, in order not to confuse and in accordance with standards as well as including the relevant explanations, (Serway & Beichner, 2010, p. 809) may have a role in this high rate of success (92.6%). It must be said that the instructors' predictions about the pre-service teachers' written responses and their corresponding percentage rates are not very accurate.

Question 2. In your opinion, what is the function of the circuit component whose symbol is given in the Figure 1?

Table 2. Pre-service teachers' responses for the functions of the circuit component given in the symbol

Written Answers	Female	Male	Total	%	Predictions of Instructors (%)
İt measures the charge density flowing through the circuit	8	1	9	16.7	-
It is related to current. It controls it and enables it to flow	7	3	10	18.5	-
It stores electrical charge	4	2	6	11.1	21.0
It stores energy	4	3	7	13.0	46.0
It is storage	5	2	7	13.0	-
Other answers (it measures resistance, it measures capacitance, it measures heat)	5	-	5	9.3	8.0
No answer	10	-	10	18.5	25.0
Total	43	11	54	100	100

When each plate of a capacitor is connected to the positive and negative terminals of a battery, the capacitor becomes charged. During the charging process, the battery does work on the flow of electrons, and then the work done is stored as electric potential energy in the capacitor (Mazur, 2016, p. 689). Instant electric shock given for cardiac arrests, by stopping irregular heartbeats to catch regular heart rhythm, is provided by the energy stored in the capacitor which is present in electroshock devices (Serway & Beichner, 2010, p. 817). The application explained determines that capacitors are normally used for storing energy. When the responses in Table 2 are examined, it can be seen that for the function of the capacitors, seven pre-service teachers (13.0%) wrote that a capacitor stored energy, six pre-service teachers (11.1%) wrote that it stored electrical charge and seven pre-service teachers (13.0%) wrote that it only stored. It can be stated that the responses of the remaining 34 teachers about the function of a capacitor do not agree. The instructors estimated that 46.0% of the pre-service teachers would write that a capacitor stored energy and 21.0% of them would state that it stored electrical charge. The predictions made reveal that the instructors do not know the students they taught about capacitors sufficiently well. They failed to ask questions, to observe while having discussions on the subject or to check their exam papers. That is to say, they failed to evaluate well enough.

Question 3. Write the formulas or equations you know about the circuit component represented by a symbol in the Figure 1.

Table 3. Equations written by the pre-service teachers about the circuit component given in Figure 1.

Written equations	Female	Male	Total	%	Predictions of instructors (%)
$C = \frac{Q}{\Delta V}$	5	3	8	14.8	33.0
$C = \frac{Q}{\Delta V}$ and $E = \frac{1}{2}C(\Delta V)^2$	1	-	1	1.9	8.0
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$	3	-	3	5.6	-
$C_{eq} = C_1 + C_2$	1	-	1	1.9	-
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$ and $C_{eq} = C_1 + C_2$	7	1	8	14.8	21.0
$C = \frac{Q}{\Delta V}$, $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$ and $C_{eq} = C_1 + C_2$	5	3	8	14.8	-
$C = \epsilon_0 \frac{A}{d}$	-	-	-	-	8.0
$C = \kappa C_0$	-	-	-	-	4.0
Other answers $\left(V = IR, C = QV, Q = \frac{m}{V}, E = VC\right)$	7	-	7	13.0	-
No answer	14	4	18	33.3	26.0
Total	43	11	54	100	100

When the responses in the last two rows of Table 3 are examined, it can be understood that 25 pre-service teachers (46.3%) could not write any equations on the capacitors. It is interesting that none of the pre-service teachers could write the equation $\left(C = \varepsilon_0 \frac{A}{d}\right)$, which presents the capacitance of the parallel plate capacitor in terms of its geometry; however, the instructors predicted that this formula would be written at the rate of 8.0%. Moreover, it is thought-provoking that the equation $\left(U = \frac{1}{2} C(\Delta V)^2\right)$, which gives the capacitor's energy, was written by only one pre-service teacher (1.9%), and the instructors estimated this response as 8.0%. It was revealed that the instructors predicted pre-service teachers who wrote the equation $C = \frac{Q}{\Delta V}$ twice more than anticipated.

Question 4. Explain the quantities and parameters in the equation/equations written for the third question.

Table 4. Pre-service teachers' explanations about the quantities and parameters written in the equations by them

Written answers	Female	Male	Total	%	Predictions of instructors (%)
Q: electrical charge, *C*: capacitance of a capacitor, *ΔV*: potential difference	10	5	15	27.8	41.0
$C_1, C_2, ..$: capacitance, C_{eq} : equivalent capacitance	4	3	7	13.0	7.0
Q: electrical charge, *E*: energy, *ΔV*: potential difference	1	-	1	1.9	11.0
ε_0 : Permittivity of free space	-	-	-	-	2.0
Other answers (*C*: constant, *C*: heat capacity, *I*: current, *R*: resistance, *V*: potential difference)	6	-	6	11.1	13.0
No answer	22	3	25	46.3	24.0
Total	43	11	54	100	100

Considering the data presented in the last two rows of Table 4, 31 pre-service teachers (57.4%) could not explain any of the quantities given in the formulas related to the capacitors. When textbooks including capacitors are examined, the first equation that is usually encountered is the formula $C = \frac{Q}{\Delta V}$. In this formula, which gives the definition of capacitance, the fact that the parameters of *C* (capacitance), *Q* (electrical charge) and *ΔV* (potential difference) could not even be explained must be considered and questioned. The instructors predicted that the rate of pre-service teachers who could not explain any of the quantities would be 37.0%. Moreover, it is thought-provoking that the pre-service teachers left the last question unanswered at a high rate (38.9%); in other words, they did not write an answer to this question. It was found that the pre-service teachers' responses about the parameters in the formulas; and the predictions of the instructors who gave them lectures and evaluated them were not quite compatible.

3.1. Pre-service teachers' views from the interviews

In addition to the written responses of the pre-service teachers to the four open-ended questions about capacitors, interviews were carried out with seven teachers who were chosen randomly among those who volunteered to participate in the interviews and had time. It was revealed during the interviews that pre-service teachers' knowledge and responses verified their written responses and were similar to them. Four statements chosen from the original responses of seven different students to the same questions are given below:

I did know that the name of the circuit component in question was a capacitor, so I wrote that. I do not remember any other thing.

I knew the function of a capacitor, but I forgot it. I wrote that it stored but I could not remember what it stored.

I can say that I answered all of the questions. In fact, I passed the course with AA.

I did not write anything for the last two questions because I don't like formulas. I am not interested in what the letters in the formulas stand for or mean.

4. Discussion, Results, and Suggestions

It was found that 62.9% of the pre-service teachers did not know the function of a capacitor, and the instructors predicted this figure to be 33.0%. It can be stated that 46.3% of the pre-service teachers could not write any equations about the capacitors correctly, and the instructors' predictions about the pre-service teachers who could not write any formulas correctly were rather different from the reality (26.0%). 57.4% of the pre-service teachers could not explain any quantities included in the formulas about capacitors. The instructors' prediction of the pre-service teachers who could not explain any quantities was 37.0%. The answers written to the open-ended questions, and the views stated by the pre-service teachers about capacitors in the interviews reveal that their understanding of capacitors was not at the desired level. The instructors' predictions show that they did not sufficiently estimate the knowledge of the students they taught, questioned, enabled to discuss the subject, guided and observed, and whose exam papers they checked; in other words, evaluated on capacitors.

Research studies (Altun, 2009; Celik et al., 2012; Demirezen & Yagbasan, 2013; Osborne, 1981; Osborne, 1983; Osborne & Freyberg, 1995; Salar et al., 2016; Sencar & Eryilmaz, 2004) reveal that students usually have difficulties on the subject of electricity. The findings of the study demonstrate that similar problems are experienced with the basic principles, concepts, quantities and equations related to the subject of capacitors.

If the instructors who teach the subject of capacitors state that a capacitor is the provider of energy required to power electroshock devices and camera flashes (Serway & Beichner, 2010, p. 809), they can attract the attention of students and cause them to be more motivated. Thus, because of addressing or giving examples from each physics subject's field of applications or contributions to our life can generally draw the interest of the respondents, they can think and question the explanations while listening to them carefully. Thinking about and questioning a subject can be regarded as the first step in learning about it.

It is important that students use their intelligence (Ranciere, 2015). Individuals should not simply accept one-sided explanations that teachers or experts give about a subject, concept or quantity. They need to think about the subject, concept or quantity they want to learn. An individual can construct a concept or quantity in his mind correctly and learn it permanently, provided he contemplates, thinks over, compares and deduces. It will be effective if the instructors include everyday activities about capacitors in the lessons in which they are going to explain to them; these activities will enable pre-service teachers to think over, contemplate and discuss the definitions, concepts and quantities. Moreover, learning the acquired knowledge at an applicable level must be considered. It is expected that a pre-service teacher who thinks that he has learned about a capacitor should know on which circuits and where to use it, and for what purposes and how it is connected. In general, the availability of information about a quantity or concept is determined by the time an individual spends on thinking about it. The evidence of learning a subject, concept or quantity depends on the individual's ability to use the acquired knowledge, but if he does not use it, then the learning that is supposed to be employed becomes worthless. In short, the knowledge that an individual thinks he has learned, but cannot put into practice or use, has little importance or significance.

References

Altun, S. (2009). Uc asamali bir testle fen bilgisi ogretmen adaylarinin basit elektrik devreleri konusundaki kavram yanilgilarinin tespiti. *Bayburt Universitesi Egitim Fakultesi Dergisi, 4*(I–II), 72–79.

Celik, H., Pektas, H. M. & Demirbas, M. (2012). Sinif ogretmenligi ogrencilerinin elektrik devrelerini kurma ve sematize etme durumlarinin incelenmesi. *M.U. Ataturk Egitim Fakultesi Egitim Bilimleri Dergisi, Sayi, 35*, 85–103.

Demirezen, S. & Yagbasan, R. (2013). 7E Modelinin basit elektrik devreleri konusundaki kavram yanilgilari uzerine etkisi. *Hacettepe Universitesi Egitim Fakultesi Dergisi, 28*(2), 132–151.

Halliday, D., Resnick, R. & Walker, J. (2014). *Fundamentals of Physics-2* (9th ed.) (Bulent Akinoglu & Murat Alev, Trans.). Ankara, Turkey: Palme Yayincilik.

Mazur, E. (2015). *Principles & Practice of Physics-2*, (1st ed.) (Abdullah VerCin & Ali Ulvi Yilmazer, Trans.). Ankara, Turkey: Nobel Akademik Yayincilik Egitim Danismanlik Tic. Ltd. Sti.

Osborne, R. & Freyberg, P. (1995). *Learning in Science: the implication children's science*. Hong Kong, China: Heinemann.

Osborne, R. J. (1981). Children's ideas about electric current. *N. Z. Science Teacher, 29*, 12–19.

Osborne, R. J. (1983). Modifying children's ideas about electric current. *Research in Science and Technological Education, 1*(1), 73–82.

Ranciere, J. (2015). *Le maitre ignorant* (Savas KiliC, Trans.). Istanbul, Turkey: Metis Yayinlari.

Salar, R., Uzun, E., Karaman, I. & Turgut, U. (2016). Fizik ogretmeni adaylarinin 12. sinif elektrik ve elektronik konusuyla ilgili bilgi duzeylerinin belirlenmesi. *Trakya Universitesi Egitim Fakultesi Dergisi, 6*(1), 41–54.

Sencar, S. & Eryilmaz, A. (2004). Factors mediating the effect of gender on ninth-grade Turkish students' misconceptions concerning electric circuits. *Journal of Research In Science Teaching, 41*(6), 603–616.

Serway, R. A. & Beichner, R. J. (2010). *Physics for Scientists and Engineers-2* (5th ed.) (Kemal Colakoglu, Trans.). Ankara,Turkey: Palme Yayincilik.

Young, H. D. & Freedman, R. A. (2009). *Sears and Zemansk's University Physics with Modern Physics* (12th ed.) (Hilmi Unlu, Trans.). Istanbul, Turkey: Pearson Education Yayincilik Ltd. Sti.