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Pre-service physics teachers' understanding level about the "electric field in the RC circuit"

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Abstract

The first condition of teaching a concept scientifically is to be understood this concept exactly by the individuals. In this sense, the understanding level of pre-service physics teachers who are the educators of tomorrow becomes an important issue. In this study, we investigated the understanding level of the pre-service physics teachers about the electric field in RC circuit during the charging and discharging of the capacitor additionally, after the capacitor is charged. The data was collected via qualitative research methods by using semi-structured interview protocol with 22 pre-service physics teachers. Content analysis method was used in data analysis and then the understanding level of the participants was determined. According to the results, nine pre-service physics teachers' understanding level was determined as "Sound Understanding" whereas eight participants were in "Partial Understanding with Specific Alternative Conception" level. The understanding level of a participant was "No Understanding", because of the irrelevant or unclear responses to the questions and four participants were determined to have some alternative conceptions. As a result; all the participants who could answer the questions, stated that an electric field occurs on the capacitor until it was charged. The participants have some alternative conceptions, especially about the electric field that occurred in the capacitor and in the resistor.

Keywords: Alternative conceptions, electric field, RC circuit, pre-service physics teachers, understanding level.

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1. Introduction

If a potential difference is applied to the two terminals of a uniform conductor wire, an electric field occurs. Owing to this, free electrons move with the help of the electric field and an electric current occurs (Giancoli, 2005). When a resistor is connected to a battery, an electric current occurs from the positive terminal to the negative terminal. The direction of the electric field is always from the higher to the lower potential. That is, the electric field occurs in the same direction as the electric current in a resistor and in the opposite direction to the electric current in the battery (Giancoli, 2005). In direct current (DC) circuits, which comprise only resistors, the current does not change in time. However, in resistor-capacitor (RC) circuits, which comprise a resistor and a capacitor, the current changes in time. While the direction of the occurring current is from the positive potential to the negative one, the electrons are in the opposite direction. In order to charge a capacitor, only one battery is sufficient. With the closure of the switch in the circuit, the electrons vibrate due to the electric field formed by the battery in the wires. This occurring electric field tends to move the electrons from the positive potential to the negative potential. For this reason, it vibrates the electrons from the battery's negative terminal to the plate nearest to this terminal. As for the electrons of the same size, it vibrates them from the other plate (near the positive terminal) to the positive terminal. In this case, the plate near the positive terminal is positive charged, while the plate near the negative terminal is negative charged. This process continues until the potential difference between the plates is equal to the battery's potential difference. Since the positive terminal and the positive plate have the same potential as soon as equilibrium is maintained, there is no longer an electric field in the wires. For this reason, more electrons cannot vibrate. The capacitor is now fully charged and is of the same potential as the battery (Halliday, Resnick & Walker, 2011). Therefore, in an RC circuit connected to a DC power supply, an electric field occurs over all circuit elements in the capacitor's charging up and discharging process. After the charging, an electric field occurs only in the battery.

Due to these complex characteristics of the RC circuit, pre-service physics teachers experience some difficulties while learning this topic. There are three stages: charging, discharging of the capacitor and after charging stage. Some pre-service teachers have modeled the electric field relationship among the circuit elements in these stages in a wrong way. The capacitor-related issues lead to some misconceptions. Previous research shows that students encounter certain difficulties related to electrical concepts (Duit, Jung & Rhoneck, 1984). In order to trace such difficulties, the present study has investigated pre-service physics teachers' understanding level of this topic. With the help of Abraham, Gryzybowski, Renner and Marek's (1992) classification, the participants' knowledge level was determined. In addition to this, their misconceptions related to RC circuits were investigated. The reasons underlying the determined misconceptions were discussed and an approach for eliminating such misconceptions was developed.

2. Method

Since the present study required an in-depth analysis, the qualitative research method was applied. Creswell (2007) states that qualitative research is the most suitable method for investigating topics with such complex components. This kind of research comprises a long-term, meticulous and detailed data collection process, and analysis and reporting of the data.

Within the scope of the study, in order to carry out comprehensive research and at the same time reflect individuals from all parts of the sample, 22 pre-service physics teachers were involved. Of the candidates who wanted to participate in the study voluntarily, a selection was made on the basis of gender, year of study, grade point average, Electricity and Magnetism course scores and the principle of maximum diversity.

The data were collected through the interviews performed with the pre-service teachers. The semi-structured interview technique was used. The interviews lasted approximately half an hour. The semi-structured questions were prepared based on textbooks used as supplementary materials at

universities. Following this, they were reviewed by three experts in the field in order to maintain internal validity (Merriam, 2009). A pilot study was carried out with four pre-service teachers who meet the sampling criteria and the questions took their final form. In addition, pre-service teachers were asked to demonstrate on the circuit scheme. These schemes were evaluated during the content analysis.

The collected sound recordings were transcribed and transferred to the computer environment. The collected data were checked by the pre-service teachers who took part in the study; thus the internal validity was checked one more time (Merriam, 2009). Content analysis was employed in data analysis. Abraham, Gryzybowski, Renner and Marek's (1992) understanding level classification was taken as the basis. This classification is as follows:

Sound Understanding (SU): Totally scientific answers

Partial Understanding (PU): Mostly scientific answers

Partial Understanding with Specific Alternative Conception (PU/AC): Alternative concepts in addition to scientific answers

Alternative Conception (AC): Non-scientific answers

No Understanding (NU): Irrelevant answers and no answer.

3. Findings

The pre-service physics teachers' understanding level of the electric field occurring after the charging-discharging and post-charging process in an RC circuit, which is applied a DC is shown in Table 1. Data analysis shows that almost half of the pre-service physics teachers (41%) have a scientific approach of the topic. As for the 36%, despite having scientific knowledge to a certain extent, they have some misconceptions. In addition, the rate of those who have only non-scientific knowledge is 18%, while 5% did not give any answer.

Table 1. The distribution of the understanding level of participants

Understanding Level	The Number of Participants	The Percentage of Participants
Sound Understanding	9	41
Partial Understanding	0	0
Partial Understanding with Specific Alternative Conception	8	36
Alternative Conception	4	18
No Understanding	1	5
Total	22	100

Pre-service teachers with "Sound Understanding" understanding level gave scientific answers to all of the questions related to the context. They explained the three stages of the process in detail as the charging of the RC circuit connected to a DC power, the post-charging process and the discharging process. They explained the physical phenomena and the electric current events within a scientific framework. To exemplify, they mentioned that during the charging and discharging of the capacitor, an electric field occurs in all circuit elements. They mentioned that after the capacitor is charged, the electric field occurs only in the battery. They stated that an electric field occurs due to the potential difference between the capacitor's plates while the capacitor charges. They told that since the battery is removed from the circuit in the discharging process, electric field might occur in the capacitor, wires and battery. A potential reason for this conclusion is the charges over the capacitor plates. After the

battery is removed, the capacitor charged on the circuit maintains the current and this current value decreases exponentially with time.

While there were no pre-service teachers with an understanding level of "Partial Understanding", there were eight participants with "Partial Understanding with Specific Alternative Conception". At this stage, pre-service teachers have various misconceptions related to the context in addition to scientific knowledge. For example, they stated that during the charging and discharging of the capacitor, no electric field will occur in the resistor or an electric field cannot occur on only the wire. In addition to these, there were some pre-service teachers who stated that an electric field will not be occurred in either the resistor or the wire. Also, a pre-service teacher stated that an electric field will not be occurred only in the battery. Some participants stated that there is a battery in the circuit during the discharging of the capacitor.

Pre-service physics teachers with "Alternative Conception" understanding level had a considerably high level of misconceptions related to the electric field occurring in the RC circuit. Replies, which contain almost no scientific knowledge, can be listed as: "There is no electric field in the charging and discharging of the capacitor in the RC circuit". In addition, there were statements like "The electric field occurs only in the capacitor but not in the DC power supply, resistor and wires". Pre-service teachers with "No Understanding" level did not provide any answers to the questions.

4. Conclusion and Discussion

Pre-service physics teachers had four different understanding levels related to RC circuits. The most frequently mentioned topic by the participants was that they never considered the RC circuit and electric field relationship. The participants explained that they thought of the topics as two independent concepts. However, they formed a pattern based on their existing knowledge during the interviews and were able to comment on the questions.

The fact that an RC circuit comprises three levels, comprising charging, discharging and post-charging, caused some confusion in the participants. Many students with alternative conceptions thought of the three processes as one. Additionally, their knowledge related to other electric circuits led them to have misconceptions. Newburg (2002) had also found that students confused LR and RC circuits, adding that they had difficulty interpreting the graphics and thus confused the two circuits.

Some of the pre-service teachers who had alternative concepts thought that electric field is only related to the capacitor. This may stem from the fact that the capacitor is given priority in the books and courses and the electric field occurring in the wires and the resistor is not highlighted.

At the same time, the interviews revealed that pre-service teachers do not exactly understand the function of the wires. It was understood that they do not know the fact that the wires also have internal resistance and function as resistors in the circuit to a small extent. This might stem from the low emphasis given to questioning in the educational system. The fact that they know the formula of resistor but can not comment on the wires shows that pre-service teachers explain the contexts on the basis of memorized knowledge.

Previous research shows that students at the same time confuse the DC (direct circuit) and AC (alternative circuit) concepts and thus have caused misconceptions (Holton, Verma & Biswas, 2008).

In conclusion, as the topics progress and their similarity increases, students have difficulty in making interpretations and confuse the contexts. For this reason, we believe that interpreting graphics and formula is important during teaching in terms of comprehension of the context and long-term catchy. Also, the applied teaching of topics, which are suitable for experimentation, will be useful.

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