# The Effects of Misconceptions on Pre-service Teachers' Ability to Constructing Simple Electric Circuits

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**Abstract**
In this study, it is aimed to determine effects of pre-service elementary school teachers' misconceptions about short circuit and open circuit on their ability to set up simple electric circuits. The sample of the research is composed of 41 teacher candidates studying at Dokuz Eylul University. Open-ended questions and semi-structured interview questions prepared by researchers were used to identify misconceptions about short circuit and open circuits. In order to determine the effect of these misconceptions, the pre-service teachers were observed in the process of establishing simple electric circuits. Findings from the open-ended questions show five different misconceptions about the short circuit, and two about the open circuit. The interviews reveal that these misconceptions are caused by three factors: extreme generalizations, the misleading terminology used in everyday speech, and misconceptions arising from past learning experience. It was also determined that the students who held these misconceptions had difficulties in establishing a simple electric circuit.
**Keywords**: Short circuit, open circuit, misconception, circuit setup

## INTRODUCTION

Studies on specific concepts constitute an important part of science education research. Zirbel (2004), defines concepts as building blocks of information that enable understanding of the world around us. Understanding the concepts and their importance in the learning process provides important information to educators (Ayas et. al., 2012). Many cognitive psychologists emphasize that people construct new knowledge based on past knowledge and beliefs (Chang et. al., 2007). However, students' preconceptions gained from informal experience may not always be scientifically accurate. The preconceptions incompatible with scientific information are called "alternative concepts", "alternative frameworks" or "misconceptions" in the literature (Garnett, Garnett & Hackling, 1995); however, in this study, the term "misconceptions" will be used.

Ideas that deviate from modern scientific thought are generally referred to as misconceptions (Steinberg & Oberem, 2000). Five types of misconceptions can be classified: biased thoughts, non-scientific beliefs, conceptual misunderstandings, mistakes originating from spoken language, and misconceptions about events (Klassen, 2009). The formation of concepts is a complex process that depends on how individuals perceive and experience, and how they acquire the information (Zirbel, 2004). Life experience varies from person to person. And so, individuals may develop different conceptions of the same subject. Many students' misconceptions stem from their experience outside the classroom (Keeley, 2012). Students consider these concepts to be reliable, and are therefore resistant to change these, because they are obtained as a result of experience. But not all misconceptions come from informal

experiences. A concept that is in fact scientifically correct can later become a misconception because of changes occurring in existing knowledge (Zirbel, 2004). Whatever the reason for a misconception, it constitutes a major obstacle to the students' learning process (Keeley, 2012). For this reason, it is very important for educators to understand the nature of misconceptions in order to provide meaningful learning.

Studies on misconceptions in electrical issues seem to focus on the following areas: electric field (Bilal & Erol, 2009; Furio & Guisasola, 1998; Pocovi, 2007; Pocovi & Finley, 2002; Törnkovist, Petterrson & Tranströmer, 1993; Saarelainen, Laaksonen & Hirvonen, 2007), static electricity (Başer & Geban, 2007), electric power, electric potential and work (Maloney, O'Kuma, Hieggelke & Heuvelen, 2001; Bilal & Erol, 2009), and direct current circuits (Bilal & Erol, 2009; Çepni & Keleş, 2006; Kibble, 1999; Küçüközer & Kocakülah, 2007; Lee, 2007; Lee & Law, 2001; Thacker, Ganiel & Boys, 1999). The basic concepts of direct current circuits are extremely important, as they constitute the basis for students' understanding of current technology. Within this knowledge, the concepts of short circuit and open circuit are crucial, as they have a critical role in the operation of a simple electric circuit, and in determining the equivalent resistance of the circuit. Without a clear knowledge in this area, serious mistakes can be made in the analysis of a circuit. Nevertheless, studies on electrical issues indicate that students have misconceptions about short circuits (Fredette and Clement 1981; Engelhardt and Beichner, 2004; Peşman & Eryılmaz, 2010; Altun 2009; Brown, Slater & Adams, 1998).

Fredette and Clement (1981) emphasize that such misconceptions include a belief that circuit-free cable connections can be neglected in circuit analysis. This creates great difficulty in circuit analysis, as students will not notice a shorted circuit element. Engelhardt and Beichner (2004) found that 17% of students who participated in their work were not able to recognize the shorted in a circuit. Although these studies highlight that students have difficulty in this area, they neglect how the misconceptions about short circuit and open circuit concepts affect the ability to set up simple electric circuits. Therefore, in this study, it was aimed to identify pre-service elementary teachers' misconceptions about short-circuit and open-circuit, and determine whether these misconceptions affected their ability to set up simple electric circuits.

## METHOD

### Participants

The participants of the research constitute 41 teacher candidates at Dokuz Eylul University Buca Education Faculty, Elementary Teacher Education Department. In order to ensure the reliability of collected data, criterion sampling method, a purposeful sampling method, was used in determining the research sample. In this approach, units of observation are constructed from persons, events, or objects with specific qualities (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2016). In this context, participants were selected from teacher candidates who had taken general physics courses.

### Data Collection

Collection of research data was carried out in three steps. First of all, written questions were given to the students (n=41) in order to determine their misconceptions about short and open circuit. The written questions were prepared by consulting two field experts. In the first two questions, students were asked to express the open and short circuit concepts, while in the last two questions, students were asked to comment by examining the circuit diagrams. In the second stage, interviews were conducted with 10 students who were determined to have misconceptions in the first stage. Semi-structured interview protocol was conducted with the same questions to gain deeper understanding about these misconceptions. The last step of the

data collection process was carried out in the physics laboratory, where students were asked to set up simple electrical circuits using supplied materials (a DC source, three bulbs and a switch). In this step, students were first asked to light a bulb by connecting it to DC source, and then light the lamp by adding a switch to the circuit. Successful students were asked to establish serial and parallel circuits using three bulbs, a switch and a DC source. This process was video recorded, using a camera focused on the circuit kit.

## RESULTS

The research findings are discussed in three sections: findings from open-ended questions, interview questions, and finally, the circuit establishment process.

### Findings from Open-Ended Questions

When the written answers were examined, it was determined that the majority of teacher candidates (69%) have some misconceptions about short circuits. These misconceptions fell into five categories. In contrast, only 22% had misconceptions about the open circuit, grouped into two categories. Table 1 shows frequency of these misconceptions.

**Table 1.** *Misconception groups regarding short-circuit and open-circuit*

| | **Misconception groups** | **f** | **%** |
|---|---|---|---|
| **Short Circuit** | Non-operation of the circuit | 8 | 20 |
| | Collision of opposite charges | 5 | 12 |
| | Over current | 6 | 15 |
| | The reaction of electric gadgets | 4 | 10 |
| | Disconnected cables | 5 | 12 |
| **Total** | | 28 | 69 |
| **Open Circuit** | Working electrical circuit | 5 | 12 |
| | Location of open end will differently effect the operation of circuit | 4 | 10 |
| **Total** | | 9 | 22 |

### Findings from Semi-Structured Interviews

Semi-structured interviews were conducted to get more detailed information about the student misconceptions determined in the previous section.

### Misconceptions Regarding Short Circuit

Eight students describe the concept of short circuit as "non-operation of the circuit". Below are quotes from interviews with two of these.

*R: What does the concept of "short circuit" mean to you?*
*$S_1$: I understand that it means non-operation of the circuit when a short circuit is called*
*R: Can you explain a little more?*
*$S_1$: Actually, I can explain this from my experience in everyday life. When an electric gadget is not working, it is said that it is short-circuited. For example, when I switched on my hair dryer, it did not work. When I took it to be serviced, they said it was short circuited. …. An electrical device with a short circuit does not work.*
*R: Why does not it work?*

*$S_1$: It does not work because it is out of order. … I do not know what exactly is inside them (electrical devices), but the breakdown of their electronic components causes a short circuit.*
*S4: I cannot make a scientific statement about short circuit, but I can say that a short circuit is non-operation of an electrical circuit.*
*R: Can you explain a little more?*
*S4: I cannot explain in detail…For example, a television that does not work has become a short circuit.*

Another finding from the written responses was that the concept of short circuit was described as a collision of opposing charges in an electrical circuit. 5 students held this view.

*S7: I know that the short circuit is the* collision *of positive and negative charges.*
*R: Could you explain a little more?*
*S7: … Short circuit occurs when the positive charges coming out of one pole of the battery collide with the negative charges coming from the other pole. The spark comes out. Sometimes a small explosion is heard.*
*R: Why do positive and negative charges collide?*
*S7: Because the charges must be spent passing through lamps. If the loads do not pass over the lamp and pass through an empty wire, they collide with each other.*

One of the most common misconceptions, held by six participants, is that the concept of short circuit is defined as "over current".

*S2: A short circuit is a kind of over current. High current causes the lamp to explode.*
*R: Could you explain a little more?*
*S2: There must be a battery or power supply for operation of an electrical circuit. Also, think that there is a lamp. There is a current that this lamp can withstand. If the current come from the battery is greater than this current which the lamp can withstand, the lamp explodes. The lamp becomes short-circuited.*
*R: Does the short circuit only occur in circuits with lamps?*
*S2: No. There may be other electrical gadgets such as irons, ovens, televisions... These gadgets have a certain current that they can tolerate. If the current comes too much, these gadgets will break down. It's called a short circuit. One time, the lamp in our house exploded in this way. My friends said it was a short circuit.*

Another finding from the written responses is that five students conceive the short circuit as "disconnected cables". Below is a quote illustrating this misconception.

*S5: …. Electricity is cut off when there is a short circuit. … If the wires do not contact each other, a short circuit occurs. Electric current cannot flow when the wires do not touch each other. In this case, there is no electricity in the circuit. For example, in a circuit consisting of a battery and a lamp, the lamp does not light up if the wires do not touch the battery or lamp.*

The latest research finding about the concept of short circuit is that students define the concept of short circuit as "reaction of electrical gadgets". Four participants seem to hold this misconception, illustrated below.

*S6: I've heard a lot about short circuit. Like something short-circuiting…. like an electronic device short-circuiting.*

*R: What is short circuit?*
*S6: It is a reaction that the device shows when encountering a problem in the electrical sense. To shut itself down.*
*R: Could you explain a little more?*
*S6: When we operate many electrical appliances at the same time, there is a decrease in energy. For example, if we run the hair dryer, the oven, and the washing machine at the same time, the energy in the circuit is reduced. This creates a problem in the circuit. Electrical gadgets shut themselves down to avoid break down.*

**Misconceptions Regarding Open-Circuit**
There were two types of misconceptions about the open-circuit (Table1). The first, held by five students, considered the open circuit as a "working circuit", described below.

*R: Could you give information about the open circuit?*
*S8: The open circuit means that the switch on the electrical circuit is closed. When the switch is closed in an electric circuit, the current flows through the circuit, and the lamp lights up. So the circuit becomes open.*

The second misconception, held by four of the participants, was that location of open end in an electric circuit will affect the operation of the circuit in different ways. To understand these perceptions, during the interview, they were asked which of the circuits in Figure 1 would illuminate the lamp.

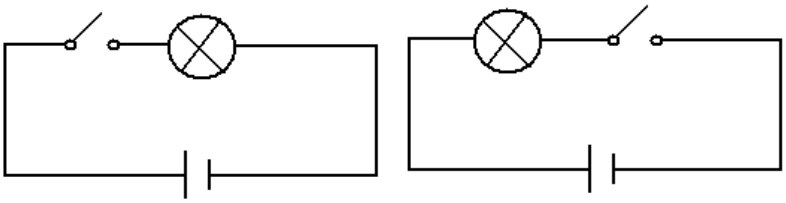



**Figure 1.** *Diagram of open circuit for interview questions*

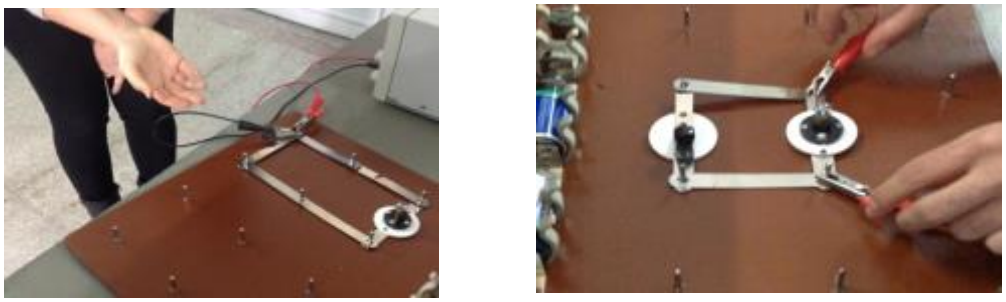
*R: What can you say about whether the lamps in these figures will light?*
*S10: While the second lamp (Fig. 1b) does give light, the first (Fig. 1a) does not.*
*R: Can you explain the reason for your answer?*
*S10: … on a battery, current flows from the positive terminal to the negative terminal. In the second figure, the current come from the positive pole of the battery and reaches the lamp. The lamp gives light because the current reaches the lamp. … In the first figure, the key is placed in front of the lamp. Because the switch is open, the current from the battery cannot reach the lamp. For this reason, the lamp does not light.*

**Findings from The Circuit-Set Up Process**
Students were required to install the following circuits using generators, lamps and conductors.

- *Circuit 1: Install a simple electrical circuit using a generator, a lamp, and conductors.*
- *Circuit 2: Install a simple electrical circuit using a generator, a lamp, a switch, and conductors. The lamp must light when the key is pressed.*

- *Circuit 3: Connect three lamps in series using a generator, a switch, and conductors. The lamps must light when the key is pressed.*
- *Circuit 4: Connect three lamps in parallel using a generator, a switch and conductors. The lamps must light when the key is pressed.*

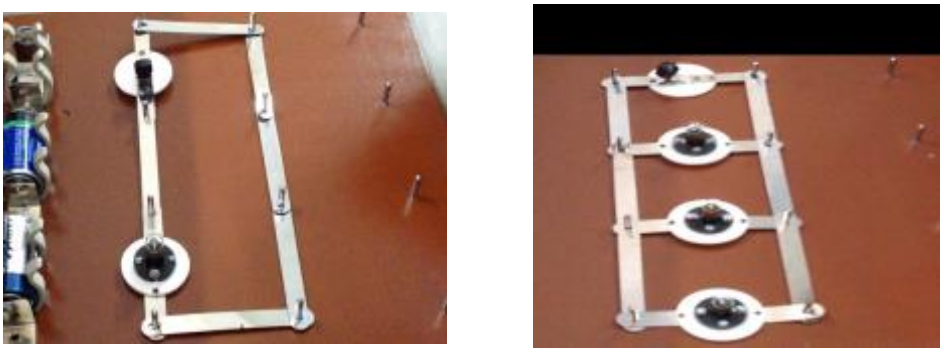
19 students were asked to set up the above circuits: five students without misconceptions, and two holding each of the misconception groups described in Table 1. The process of setting up the circuit was video recorded. In the final stage of the study, it was determined that all students without misconceptions about short and open circuit were able to set up all circuits correctly, while the two students who defined the short circuit as "non-operation of the circuit" failed. The first failed to serialize a lamp with a generator (first circuit), while the second failed to add a key to this circuit (second circuit). Figure 2 shows these circuits, respectively.



(a) (b)

**Figure 2.** *Circuits established by students who defining the short circuit as "non-operation of the circuit".*

It was determined that the two students who defined the short circuit as "the collision of opposite charges" correctly established all the circuits. However, the two who defined the short circuit as "over current" failed in the circuit establishment process. One failed to serialize the lamp, the switch and the generator, and the other failed to establish the parallel circuit, shown in Figure 3.



(a) (b)

**Figure 3.** *Circuits established by students defining the short circuit as "Over current".*

One of the students who defined the short circuit as "reaction of electrical gadgets" succeeded in establishing all circuits, while the other failed to establish the parallel circuit due

to an error similar to in Figure 3b. Finally, it was determined that only one student who hold misconception about open circuit, failed to set up circuits. The circuit established by this student is seen in Figure 4.

**Figure 4.** *Circuits established by a student who has misconception about open-circuit*

## DISCUSSION AND CONCLUSION

The research findings show that the vast majority of students have at least one misconception about short circuits. Approximately 20 percent of the participants described the short circuit as "non-operation of the circuit". It is understood that these misconceptions stem from students drawing on their daily experiences, as shown by examples of events encountered in daily life, rather than seeking a scientific explanation. When these examples are examined, it is understood that the students' conceptualization of short circuit is primarily associated, consciously or unconsciously, with the term short circuit used generally to describe failures in electrical household appliances. This situation shows that students' misconceptions arise from making over-generalizations, i.e., they tend to associate the concept of short circuit with the failure of a device. According to Yağbasan and Gülçiçek (2003), over-generalization is an important source of misconceptions. Yıldırım, Nakiboğlu and Sinan (2004) give further support to the important role of over-generalization in the formation of misconceptions.

Another misconception identified in research is the idea that the short circuit is due to the collision of opposite charges on the circuit. When examined the interview findings, it is seen that this notion stems from misconceptions arising from inaccurate past understandings of electric current. One of these misconceptions is called "clashing currents model", in which current is erroneously thought to flow out of the battery's negative and positive poles, and lose its energy by clashing (Osborne, 1983). Students who hold this misconception consider that the short circuit is caused by the collision of the opposite charges on a conductor, and although they understand that a circuit element will be shorted if its ends connected with a conductive wire, they are unable to give a scientific explanation for the short circuit concept.

Six students described the short circuit as an "over current". When interview findings are examined, it appears that this explanation also arises from association of short circuit concept with daily life experiences. A bursting light bulb example was given by one student. Describing this event as a "short circuit" in daily conversation causes students to associate over current with the short circuit, suggesting that origin of this misconception is based on experiences in daily life, and the commonly used term to describe them.

Another finding from the study is that students define the concept of short circuit as "disconnected cables". In the interview, one student described the open circuit state, labeling it as a short circuit. This shows that some students are not clear of the distinction between the concepts of short circuit and open circuit.

The findings of the research show that students are more successful in defining the open circuit concept. There are only two types of misconception in this area. In the first of these, the students defined the open circuit as a "working electrical circuit". It seems that the underlying cause of this misconception is the terminology used. The term "open" in Turkish translation denotes that a light or television is currently in use. This causes students to define the open circuit as "working circuit". A similar finding has also been reported by Kucukozer and Kocakulah (2007). The second misconception in this issue is the opinion that different positions of the open end have a different effect on the working of the circuit. Students consider that the lamp lights when the open ends are between the lamp and negative pole of the battery. Interview findings show that this misconception also derives from past misunderstandings which have taken root in the students' consciousness.

The current findings show that all five students no misconceptions about short circuit and open circuit are able to set up simple electrical circuits without difficulty, while most students with misconceptions made incorrect connections. All mistakes but one was caused by the short-circuiting of the circuit elements. When examining Figure 2a, it is seen that the generator is short-circuited, and the lamp will be short-circuited when the switch is turned on. In Figure 2b, it is seen that the student set up the circuit by short-circuiting the lamp. It is also seen that the student short-circuited the generator by connecting its positive and negative terminals to the same point. A similar mistake is seen in Figure 3a. Although switch and lamps are connected in series, the points that need to be connected to the generator are short-circuited, so when the generator connects to the circuit, it will be short-circuited. In Figure 3b, it is seen that the student connected three lamps in parallel to each other, but these will be shorted when the switch is closed. The findings showed that the majority of the students who set up a faulty circuit do so due to misconceptions about the short circuit.

Although determining students' misconceptions is a common topic in the literature, there has been no investigation of the effects of these misconceptions on the experimental processes. These researches show that teacher candidates with misconception about short circuit have difficulties in setting up simple electric circuits. Further research could focus on examining the negative effects of specific misconceptions on the successful conduct of experimental processes.

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