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Comparative Study of Secondary School Students' and Pre-Service Teachers' Misconception about Simple Electric Circuit

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Abstract

The purpose of this study is to compare the misconceptions of secondary school students (junior and senior high school) and pre-service physics teachers about simple electrical circuits. The study involved 92 people consisting of 30 junior high school students, 32 senior high school students, and 30 pre-service physics teachers. The diagnostic misconception instrument was adapted from the Simple Electric Circuits Diagnostic Test (SECDT). Data were analyzed by descriptive and inferential analysis. The results of the study indicated that there are 11 misconceptions types that the student had. The clashing current is a type of misconception that is most often found both in high school students and in pre-service teacher. The inferential test showed that there were significant differences of misconception scores among junior high school students, senior high school students, and pre-service physics teachers (KW=12,689, df=2, $p< 0.05$). Teachers could use the misconception profile as a consideration in planning classroom instruction.

Keywords: electrical circuits, junior high school students, misconceptions, pre-service physics teachers, senior high school students

INTRODUCTION

Research related to misconceptions in physics learning has received much attention in recent years. Based on a bibliometric study conducted in 2015, misconceptions came in 8th position as the most frequently used keyword in physics education research (Jamali et al., 2015). Students' misconception was interesting to study. Therefore, various studies appear on some specific topics in physics (Docktor & Mestre, 2014). Some examples of physics topics that had been studied on misconceptions field are mass and gravity (Fadaei & Mora, 2015; Syuhendri, 2019), temperature and heat (Putri et al., 2019), sound and waves (Eshach et al., 2018), electricity (Bilal & Erol, 2009; Hussain et al., 2012; Turgut et al., 2011), and several other physics topics.

One of the physics misconceptions topics that has been studied a lot is the electrical circuit topic. There were several types of research misconceptions that have been conducted related to electric circuit misconception such as research and development about diagnostic instruments of electrical circuit misconception (Peşman & Eryılmaz, 2010), research on investigations of students' misconceptions (Bilal & Erol, 2009; Hermita et al., 2018; Sree Harsha et al., 2015), and research on the effectiveness of learning models or methods in reducing students' misconceptions (Afra et al., 2009; Dilber, 2012). The results of some studies showed that electrical circuit topics were widely misunderstood by students (Hussain et al., 2012; Küçüközer & Kocakülah, 2017; Turgut et al., 2011).

The construction of a scientific concept can be interfered with by misconceptions. Docktor & Mestre (2014) stated that misconceptions could interfere with the understanding of scientific concepts that students were built in the science class. On the other hand, they have an impact on the construction of the concepts being studied. They

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can also be a problem to understand several concepts that are related (Cetin-Dindar & Geban, 2011). For example, students who have misconceptions in simple electrical circuits may also have misconceptions in alternating current circuits. This condition occurred because students failed to integrate the concepts that they had learned with meaningful concepts (Novak, 2002).

The explanations above imply that investigating and mapping students' misconceptions is essential. A good understanding of the students' misconceptions can help teachers and students to improve their learning process quality. The students' misconception profile not only can be used as a basis for making learning programs but also it can be used as a basis for making curriculum at the next level (Chu et al., 2008). In addition, students' misconception profiles at the secondary school level can also be used as considerations for curriculum development at the university level. If the teacher does not know the misconceptions of his students, the teacher will have difficulty to teach his students (Moodley & Gaigher, 2017).

However, like research conducted in several countries, most misconception studies in Indonesia were conducted at the university level. Docktor & Mestre (2014) stated that most of the current misconception studies were carried out on the undergraduate level. In the Indonesian context, there were several studies related to misconceptions in electricity. Setyani, Suparmi, Sarwanto, & Handhika (2017) found six types of misconceptions experienced for 49 physics education students in Universitas Sebelas Maret on simple electrical circuit topic. Another study like Hermita et al. (2018) found three kinds of electricity misconceptions for 41 pre-service teachers at the University of Riau. Both studies only diagnose student misconceptions at the university level. However, this current study not only diagnosed students' misconceptions at one level of education but also compared misconceptions experienced by students at three levels of education, namely between junior high school students, senior high school students, and undergraduate students (pre-service physics teachers).

This study aimed to compare students' misconceptions at the secondary school level (junior and senior high school) with pre-service physics teachers. The study also aimed to diagnose and describe the types of students' misconceptions in secondary school and pre-service physics teachers. It is expected that the results of this study give a value for teachers and lecturers in designing effective learning in order to overcome student misconceptions. Likewise, the next researcher is expected to be able to make the results of this study as a basis for finding the right way to reduce misconceptions in students on electrical circuit topics.

METHOD

This research is a quantitative descriptive study to compare the misconception of secondary school students and pre-service physics teachers. The study was conducted at the secondary school and the undergraduate program. In Indonesia, secondary school was divided into two levels. They are junior high school (about 13 until 15 years old) and senior high school (about 16 until 18 years old) (Faisal & Martin, 2019). The secondary school in this study refers to junior high school and senior high school. The junior high school involved was a public school which is located in Kamulan Village, Durenan Sub-district, Trenggalek Regency, while the senior high school involved was a private school which is located in Malang City and not as one of the favourite schools, while the pre-service physics teachers involved are students in physics education department at one of the state universities in Indonesia. This college is one of the institutions that is tasked to prepare teachers and education staff in Indonesia.

Table 1. Categorization of The Types of Students Answer

Level 1	Level 2	Level 3	Category
True	True	Sure	Scientific Knowledge
True	False	Sure	Misconception
False	False	Sure	Misconception
False	True	Sure	Error
True	False	Not Sure	Lack of Knowledge
False	True	Not Sure	Lack of Knowledge
True	True	Not Sure	Lack of Knowledge
False	False	Not Sure	Lack of Knowledge

Adapted from Kaltakçi & Didiş (2007)

Table 2. Types of Misconception Based on Alternative SECDT Instrument Answers

Types of Misconceptions	Answer Option That Indicate Misconception
1. Sink model	1.1 a, 1.2 a, 1.3 a; 10.1 a, 10.2 b, 10.3 a; 10.1 b, 10.2 b, 10.3 a
2. Attenuation of models	4.1 c, 4.2 c, 4.3 a; 4.1 b, 4.2 c, 4.3 a
3. Shared current models	3.1 b, 3.2 c, 3.3.a; 3.1 a, 3.2 c, 3.3.a; 4.1 d, 4.2 c, 4.3 a; 5.1 b, 5.2 c, 5.3 a; 5.1 a, 5.2 c, 5.3 a
4. Clashing current model	1.1 b, 1.2 b, 1.3 a; 10.1 a, 10.2 a, 10.3 a
5. Empirical rule model	4.1 b, 4.2 a, 4.3 a; 7.1 b, 7.2 b, 7.3 a; 12.1.a, 12.2.b, 12.3 a
6. Short circuit misconception	8.1 b, 8.2 b, 8.3 a; 8.1 c, 8.2 c, 8.3 a; 10.1 a, 10.2 c, 10.3 a; 12.1 b, 12.2d, 12.3 a
7. Power supply as a constant current source model	3.1 c, 3.2 a, 3.3 a; 3.1a, 3.2.a, 3.3 a; 5.1 c, 5.2 e, 5.3 a; 9.1 d, 9.1d, 9.3 a
8. Parallel circuit misconception	5.1 a, 5.2 a, 5.3 a
9. Sequential reasoning	9.1 a, 9.2 a, 9.3 a; 9.1 c, 9.2 b, 9.3 a
10. Local reasoning	2.1 a, 2.2 a, 2.3 a; 5.1 a, 5.2 b, 5.3 a; 12.1 a, 12.2 c, 12.3 a
11. Current flow as water flow	6.1 a, 6.2 a, 6.3 a; 7.1 c, 7.2 a, 7.3 a; 11.1 a, 11.2 b, 11.3 a

Adapted from Peşman & Eryılmaz (2010)

The sample in the study was taken by using the convenience sampling technique. The number of samples involved was 92 samples consisting of 30 junior high school students, 32 senior high school students, and 30 pre-service physics teachers. The junior and senior high school students were in a third grade of mathematics and natural sciences class, while the pre-service physics teacher was in the third year of undergraduate level. All the participants have learned the electrical topic.

The instrument in this study adapted from the Simple Electric Circuits Diagnostic Test (SECDT) instrument. SECDT instrument is a three-tier instrument developed by Peşman & Eryılmaz (2010) with the reliability of 0.69. SECDT consists of 12 items, where each item consists of three levels. Peşman & Eryılmaz (2010) states that SECDT is very accurate in measuring the misconception of simple electrical circuits. In addition, not only SECDT can distinguish students who have misconceptions and scientific knowledge, but also it can identify the types of misconceptions based on responses that are given based on the guidelines in Table 2.

Data analysis was performed with descriptive and inferential statistics. Descriptive statistics were carried out by categorizing the responses of students' answers based on the three tier-test responses categories, as shown in Table 1. Data were described and classified into four categories (i.e. scientific knowledge, misconception, errors, and lack of knowledge). In addition, data is categorized based on the type of students' misconceptions. The types of misconceptions can be identified based on the response of the SECDT instrument, as shown in Table 2. Testing the significance of differences in educational level towards changes in misconception was done by inferential statistics. The variances of 3 sample groups are equal to the proportion (homogenous); $F(2, 89)=2.594$, $p=0.08$. This data showed the samples of three different groups have relatively the same characteristics (OECD, 2008). However, the normality data test showed the data was not normally distributed. Therefore, the inferential statistics were performed by Kruskal-Wallis nonparametric statistics. Kruskal-Wallis statistics can be used in non-experimental studies that use three groups of independent variables or more, and the dependent variable is ordinal or if the data is not normally distributed (Morgan, 2004).

RESULTS AND DISCUSSION

The responses of junior high school students, senior high school students and pre-service physics teachers on the SECDT instrument can be categorized into four categories, as shown in Figure 1.

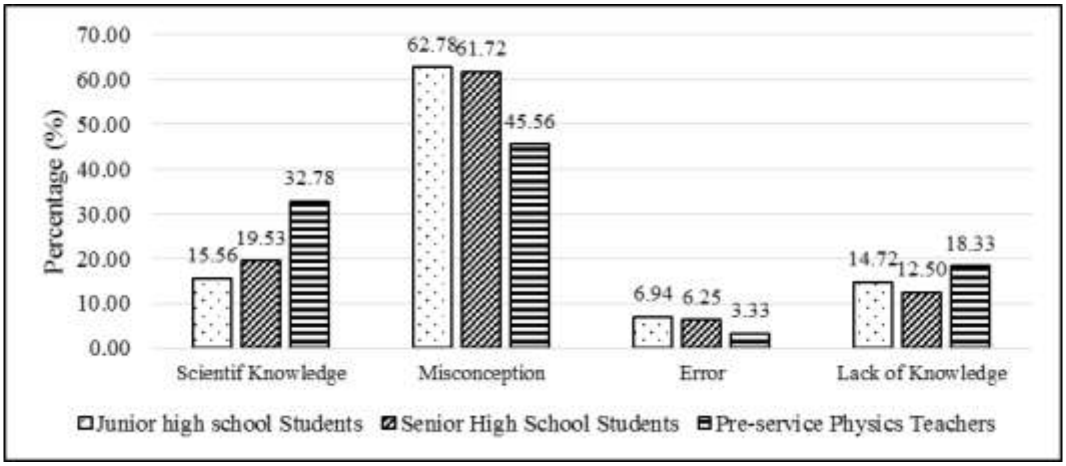


Figure 1. Average Percentage of Instrument Decisions Three Tier SECDT

Figure 1 shows that the percentage of junior high school students, senior high school students and pre-service physics teachers whose misconception is greater than the other three categories (i.e. scientific knowledge, error, and lack of knowledge). In detail, the misconception percentage of junior high school students is more significant (62.78%) than senior high school students (61.72%) and pre-service physics teachers (45.56%). Figure 1 also shows that the scientific knowledge category of pre-service physics teachers is higher than secondary school students. It is about 32.78% of pre-service physics teachers have mastered the concept of a simple electric circuit. This number is higher than the percentage of scientific knowledge of senior high school students (19.53%) and junior high school (15.56%).

The distribution of the types of misconceptions experienced by students can be identified through the response of answers to the SECDT instrument. The distribution of student misconceptions types at three levels of education can be seen in Table 3.

Table 3 shows the percentage of types of misconceptions experienced by secondary school students and pre-service physics teachers is quite varied. At higher levels of education, there are several types of misconceptions that have decreased (i.e. sink models, shared current models, empirical rule models, parallel circuit misconceptions, and current flow as water flow), have increased (i.e. attenuation models, short circuits misconception and power supply as a constant current source model), and there are also some that are inconsistent (i.e. clashing current model, sequential reasoning and local reasoning).

The empirical rule model is a type of misconception that has decreased quite dramatically with increasing levels of education. This type of misconception decreased from 13.53% in junior high school students to 7.69% in senior high school students and to 0.82% in pre-service physics teachers. The opposite occurs in the type of misconception power supply as a constant current source model which has increased gradually from 0.59% in junior high school students to 2.75% in senior high school students and 14.75% in pre-service physics teachers.

Table 3. Distribution of Misconceptions Percentage of Junior High School Students, Senior High School Students, and Pre-service Physics Teachers

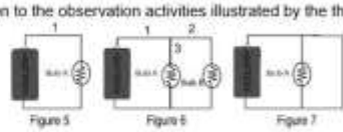
Type of Misconceptions	Percentage of Misconceptions (%)		
	Junior High School Students	Senior High School Students	Pre-service Physics Teachers
Sink Model	1.76	1.65	1.64
Attenuation Model	0.59	1.10	3.28
Shared Current Model	17.06	13.74	8.20
Clashing Current Model	21.76	28.57	18.85
Empirical Rule Model	13.53	7.69	0.82
Short Circuit Misconception	12.35	17.58	27.05
Power Supply as A Constant Current Source Model	0.59	2.75	14.75
Parallel Circuit Misconception	2.94	2.20	1.64
Sequential Reasoning	1.18	1.10	4.10
Local Reasoning	13.53	12.09	13.11
Current Flow as Water Flow	14.71	11.54	6.56
Total	100	100	100

There are two items that show different results than the other items are. They are question number 5 and question number 8. In question number 5, there are differences in the types of misconceptions experienced by students and pre-service physics teachers; while, in question number 8 the percentage of misconceptions among junior high school students, senior high school students, and pre-service physics teachers are relatively the same. The distribution of student answers to questions number 5 and number 8 can be seen in Figure 2 and Figure 3.

There are two items where students have a high misconception, namely in item number 5 and item number 8. In item number 5, students are not able to determine the difference between the electric current in a circuit with one resistor with another circuit that has two resistors installed in parallel. On question number 5 tier 1, most of the junior high school students (70%) and senior high school students (59.37%) choose option a. In tier 2 junior high school students (43%) and senior high school students (40.62%) dominantly choose option c. in tier 3, the percentage of junior and senior high school students believe are 90% and 81.25% respectively. Based on Table 2, this answer type (5.1 a, 5.2 c, 5.3 a) indicates that junior and senior high school students experience a type of misconception shared current model. It means that junior and senior high school students consider the electric current to be divided evenly on each electrical device (bulb) installed in the circuit. Different things happened to pre-service physics teachers where there were about 50% of students choosing option c in tier 1, and 43% choosing option e in tier 2 and about 80% were sure about the answers they chose. This answer combination (5.1 c, 5.2 e, 5.3 a) indicates that most pre-service teachers have a misconception about power supply as a constant source. This means that pre-service physics teachers believe that each power supply or battery provides a constant electric current instead of a constant energy source. In question 5, there are differences in the types of misconceptions experienced by secondary school students and pre-service physics teachers.

Problem Number 5

Pay attention to the observation activities illustrated by the three pictures of the electrical circuit below!



An observation activity is carried out with the following steps.

- An electric circuit is made using a battery and a bulb as shown in Figure 5.
- Bulb B is added to the previous circuit (Figure 3) in parallel. The Circuit is obtained as shown in Figure 6.
- Bulb B is then replaced with a connecting cable. The circuit image is obtained as shown in Figure 7

5.1 Based on the observation activities above, the comparison of the amount of electric current at point 1 in Figure 5 with the amount of electric current at point 1 in Figure 6 is ...
   a) Electric current in Figure 5 is greater **(JHSS: 70%; SHSS: 59.37%; PSPT: 37%)**
   b) *Electric current in Figure 6 is greater **(JHSS: 20%; SHSS: 21.88%; PSPT: 13%)**
   c) Electric current in Figure 5 and Figure 6 is equal **(JHSS: 10%; SHSS: 18.75%; PSPT: 50%)**

5.2 Which of the following is the reason for your previous answer?
   a) Because there are two bulbs in Figure 6 so that the total resistance is greater **(JHSS: 27%; SHSS: 34.37%; PSPT: 20%)**
   b) In Figure 6, the electric current comes from the battery and is divided into two branches **(JHSS: 17%; SHSS: 9.38%; PSPT: 7%)**
   c) Batteries supply one bulb in Figure 5 while in Figure 6 must supply two bulbs **(JHSS: 43%; SHSS: 40.62%; PSPT: 23%)**
   d) *Total resistance in Figure 6 is smaller than Figure 5 **(JHSS: 7%; SHSS: 0%; PSPT: 7%)**
   e) Electric current in both images is not divided into existing branches **(JHSS: 7%; SHSS: 15.63%; PSPT: 43 %)**
   f) ....

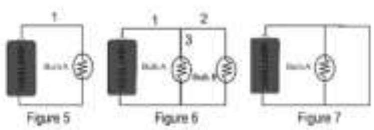
5.3 Are you sure of the answers given in the two previous questions?
   a) * Sure **(JHSS: 90%; SHSS: 81.25%; PSPT: 80%)**
   b) Not sure **(JHSS: 10%; SHSS: 18.75%; PSPT: 20%)**

* =answer key
JHSS= junior high school students
SHSS= senior high school students
PSPT= pre-service physics teachers

Figure 2. Problem number 5 about the difference between an electric current at a point in a series consisting of one resistor with another circuit with two resistors installed parallel

Problem Number 8

Pay attention to the observation activities illustrated by the three pictures of the electrical circuit below!



An observation activity is carried out with the following steps.

- An electric circuit is made using a battery and a bulb as shown in Figure 5.
- Bulb B is added to the previous circuit (Figure 3) in parallel. The Circuit is obtained as shown in Figure 6.
- Bulb B is then replaced with a connecting cable. The circuit image is obtained as shown in Figure 7.

8.1 Based on the picture above, then the brightness ratio of bulb A in Figure 6 and Figure 7 is ...
   a) *The bulbs in Figure 6 are brighter than figure 7 **(JHSS: 17%; SHSS: 15.62%; PSPT: 17%)**
   b) The bulb in Figure 7 are brighter than figure 6**(JHSS: 73%; SHSS: 71.88%; PSPT: 63%)**
   c) The bulbs in Figure 6 and Figure 7 the same is clear **(JHSS: 10%; SHSS: 12.5%; PSPT: 20%)**

8.2 Which of the following is the reason for your previous answer?
   a) *In Figure 7, there is no electric current flowing in bulb A **(JHSS: 7%; SHSS: 18.75%; PSPT: 13%)**
   b) in Figure 6, an electric current is used by two bulbs, while in Figure 7 it is only used by one bulb **(JHSS: 80%; SHSS: 68.75%; PSPT: 73%)**
   c) In both images, the electric current is divided **(JHSS: 7%; SHSS: 12.5%; PSPT: 10%)**
   d) ....

8.3 Are you sure of the answers given to the two previous questions?
   a) * Sure**(JHSS: 90%; SHSS: 93.75%; PSPT: 77%)**
   b) Not sure **(JHSS: 10%; SHSS: 6.25%; PSPT: 23%)**

* =answer key
JHSS= junior high school students
SHSS= senior high school students
PSPT= pre-service physics teachers

Figure 3. Problem number 8 about the difference in brightness between a series of parallel bulbs and other circuits which are briefly connected between the positive and negative poles of the battery

In tier 1 questions number 8, most junior high school students (73%), senior high school (71.88%), and pre-service physics teachers (63%) choose options b. In tier 2 the most of junior high school students (80%), senior high school (68.75%), and pre-service physics teachers (73%) choose options b. In tier 3, about 90% of junior high school students, 93.75% of senior high school students and 77% of pre-service physics teachers are sure to their answers. Secondary school students and pre-service physics teachers answer (8.1 b, 8.2 b, 8.3 a) indicate that they have a type of short circuit misconception where they are not able to determine the difference in bulbs that are arranged in parallel with the circuit in which there is a short circuit between positive and negative poles.

Variance analysis showed that there were significant differences of misconception scores experienced among junior high school, senior high school students, and pre-service physics teachers on simple electrical circuit topics (KW = 12,689, df = 2, $p < 0.05$). Furthermore, the results of Dunn-Bonferroni's statistical test on misconceptions experienced by students showed that significant differences only occurred between junior high school students and pre-service physics teachers ($p < 0.05$); and between senior high school students and pre-service physics teachers ($p < 0.05$). There is no significant difference between misconception scores obtained by junior high school students and senior high school students ($p > 0.05$).

There was a significant difference between misconception scores of secondary school students and pre-service physics teachers. However, there was no significant difference between misconception scores of junior high school students and senior high school students. The empirical rule model is a type of misconception that has decreased quite dramatically with increasing levels of education. In contrast, the kind of misconception of the power supply as a constant source model increases gradually with increasing education level. Clashing current models and current shared models are a type of misconception whose percentage is relatively high for secondary school students. On the other hand, the most dominant type of pre-service physics teachers' misconceptions is the power supply as a constant source model and short circuit misconception.

The decrease in students' misconceptions with increasing levels of education is in line with Bayraktar (2009), which found that student misconceptions decreased with increasing years of schooling. Despite the decline, the misconception of secondary school students and pre-service physics teachers is still relatively high. The misconception is always present in learning, according to Masson, Potvin, Riopel, & Foisy (2014) that even an expert allows us to experience misconceptions in his brain's neural network so that he can disturb him in giving a scientific explanation. This might happen because students and students generalize on the cases they have experienced and make their own knowledge even before learning ends (Wijaya, 2016).

The misconception of junior and senior high school students is not significantly different. Differences in school types may be the cause of this finding. The junior high school involved in the study was a public school, while the high school involved was a non-favourite private school in line with the OECD report (2016) that students in public schools in Indonesia have a higher ability (scientific literacy) than students in private schools. This could mean that the ability of state junior high school students and the ability of private senior high school students are relatively similar.

There were some types of misconceptions that had decreased, and those that had increased with increasing educational levels. The Empirical rule model has reduced with increasing levels of education. Students who experience this type of misconception assumed that the farther the bulbs were from the battery, the dimmer the bulbs will be. Meanwhile, power supply as a constant source model has increased with increasing levels of education, where many pre-service physics teachers assume that batteries were a constant source of current not as a constant source of energy. This result was in accordance with the research of Setyani et al. (2017) that many students assume that the current flowing in the circuit was always the same for all types of circuits.

The clashing model is a type of misconception in which students understand that an electrical device can work when positive electricity and negative electricity meet and collide inside an electrical device (Sencar & Eryilmaz, 2004). This type of misconception has decreased with increasing levels of education. At a higher level of education, understanding that the distance of the bulb to the battery does not affect the bulb. The farther the bulbs from the battery do not make the bulbs fainter. Most secondary school students have shared current models as a type of misconception. In this type of misconception, students assume that the current is evenly divided into each electrical device in the circuit (Peşman & Eryılmaz, 2010). The same condition was found by Sencar & Eryilmaz (2004) that many students ignored the form of the circuit and assumed that the electric current was at all points.

Pre-service physics teachers experience a greater misconception than secondary school students on the type of misconception power supply as a constant source model and short circuit misconception. The power supply as a constant source model was a type of misconception that was also found in the Küçüközer & Kocakülah (2017) study that many students were not able to distinguish the concept of energy and electric current. As a result, they assume that batteries were a constant source of current not as a constant source of energy (Lee & Law, 2001). Short circuit misconception in pre-service physics teachers also has a large percentage. This finding is different from the results of a study by Hussain et al. (2012) which found that only a few students (8.5%) had misconceptions about short circuits.

The implication of the results of this study in learning is that teachers and lecturers can make a profile of misconception as a consideration in making the learning design. There were several important things that were underlined in this study regarding students' misconception types. Secondary school teachers should be able to find strategies in eliminating the types of misconceptions that were still relatively high such as clashing current models, shared current models, and short circuit misconception. At the undergraduate level, lecturers need to consider that many students experience misconceptions in the type of power supply as a constant source model and short circuit misconception. Especially in the type of short circuit misconception, secondary school students and pre-service physics teachers need to be directed to pay attention to cables that are not installed with electrical devices (short circuit) when analyzing circuits. They can be invited to carry out simple experiments on short circuits to have the right scientific knowledge. According to Akınoğlu & Karsantık (2016), most of the pre-service teachers believed that being open-minded was the most important attribute for the education future. Teachers and lecturers can make the findings of misconceptions as a topic for discussion and facilities for developing conceptual perceptions in teaching (Moodley & Gaigher, 2017). However, some research results showed that it was very difficult to overcome misconceptions in students' minds (Cetin-Dindar & Geban, 2011; Docktor & Mestre, 2014).

There were several limitations in this study, including the limited number of samples and secondary schools involved in different statuses (i.e. public junior high school and private senior high school). Therefore, the researcher suggests further research with a larger number of samples so that it has a significant power to be generalized. Research can also be done by looking at differences in misconceptions between public schools and public schools or between private schools and private schools. Therefore, the differences in misconceptions of junior and senior high school students can be seen well.

CONCLUSION

Based on the results and previous discussion, it can be concluded that there was a significant difference between the misconception scores of secondary school students and pre-service physics teachers. Nevertheless, there was no significant difference between misconceptions experienced by junior and senior high school students. In general, the percentage of misconceptions had decreased with increasing levels of education. There were several types of misconceptions experienced by secondary school students and pre-service physics teachers. The empirical rule model is the types of misconceptions that have dropped gradually by increasing educational level. On the other side, the power supply as a constant source model is a type of misconception that has progressively increased by increasing educational level.

Secondary school students' misconceptions have relatively high in several types of misconceptions. They are clashing current models and shared current models. Pre-service physics teachers experience a more significant misconception than secondary school students on the power supply as a constant source model misconception and short circuit misconception. Teachers and lecturers can use misconceptions profile as a reference in planning and implementing classroom learning. There are some ways to overcome some limitations in this research. Research in simple electric circuit misconceptions can be continued with a larger number of samples and more diverse types of schools.

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