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YASMINE KHAIRUNNISA - MISCONCEPTION: WHAT COULD BE BEHIND IT?

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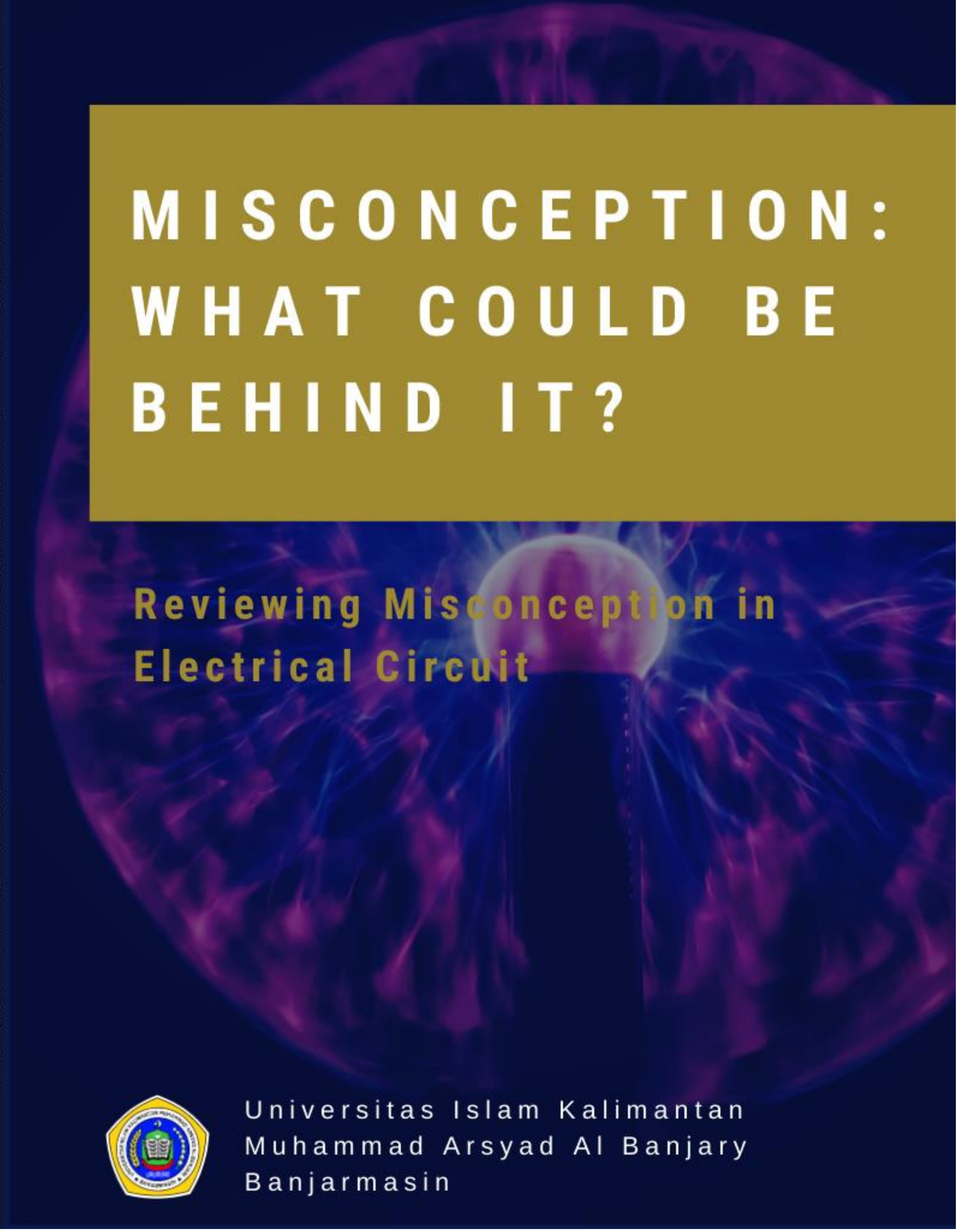

MISCONCEPTION: WHAT COULD BE BEHIND IT?

Reviewing Misconception in Electrical Circuit

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MISCONCEPTION: WHAT COULD BE BEHIND IT?

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I hope that this book could be any help for those who want to do research concerning about misconception, also be reference to any study relating to this field. At last, I wish that this book would be beneficial to anyone in education field.

Banjarmasin, 2020

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Preview

A misconception has been seen as an obstacle in science learning so that it needs to be eliminated to improve students' performance in science. This study focuses on students' misconceptions in electric circuit; it aims to find out the common misconceptions held by Indonesian students as well as students from other countries by comparing the misconceptions found in the Indonesian result with the misconceptions found in other countries from previous studies to see whether there is difference between both results. The misconception from different school type and gender is also compared to define the possible factors affecting it. The sample is 16-17 years old students from three types of high schools in Indonesia: religious, vocational, and public school. The instrument used in the research is multiple choice questions about electric circuit as many as 9 items (20 items including sub items). The analysis of data is done by determining the frequencies of students' options on each item generally, item with most false answers is considered as misconception; then, students' answers based on school type and gender are analysed by taking their confidence into account.

The research result shows that students have the misconceptions on the notion of relationship between voltage, current, and resistance, which is known as Ohm's law. Generally, students get the most false answers on item 3c (58 of 64 students) which is related to the change of current when variable resistance is increased; it refers to students' belief about battery as the source of constant current. On the other hand, the least common misconception is found on the basic conception about electric current in a series circuit (18 of 64 students) which states that current is the same everywhere on the circuit. Based on school type, religious school students have the most misconceptions on most items and public school students perform better than students from another two schools. Research result also shows that religious school students have the lowest confidence compared to other schools, whilst both vocational and public school students have a slightly similar confidence rate. Based on gender, male students have more confidence overall; specifically, male students are better in identifying pictures and female students are better in theoretical problem. Other than school type and gender, previous reports stated that language, instruction, efficacy, confidence, and interest also play a role in affecting students’ conception.

Chapter 1 **Introduction**

1.1 Background and Rationale

One of the goals in science learning is to learn the scientific knowledge correctly in order to apply it in daily life. To achieve this goal, it is important to have the correct conception in learning. However, experience plays a role in building knowledge (Sencar & Eryilmaz, 2004); therefore, it is undeniable for children or students will have various conceptions about what is going on around them, such as scientific phenomena, albeit those conceptions are not always the correct ones. A wrong preconception is called a misconception. In this case, students' preconception before they learn scientific knowledge might affect their construction of knowledge in the future. However, Pine et al. (2001) stated that misconception might also be introduced during teaching, as they showed that the wrong conceptions also came from teachers. Read (2004) stated that changing these wrong conceptions is difficult, as they are been planted in students' minds even before they receive new knowledge.

Misconception has been seen as an obstacle in science learning; most previous studies have addressed misconception as a barrier to students' comprehension of scientific knowledge (Azizoğlu & Geban, 2004) and so it should be eliminated to improve students' performance in science. However, misconception could also be represented as alternative conception, with the purpose of defining it not in negative terms, but in a positive manner, as will be discussed in this study. This study focuses on students' misconception in physics, particularly in electric circuit matter, as this has been shown to be one of the most difficult topics for students in secondary high schools (Purba & Depari, 2008). As secondary school is the most important stage for students in Indonesia, it is essential to find out what kind of misconceptions they are holding in order to help students solve or handle these in the correct way.

Analysing misconception broadly is quite a challenge for researchers, as it cannot be assessed through examination scores or daily performance only, or in other ways; therefore, an appropriate instrument is needed to measure the degree of misconception in

Indonesian students. As Indonesia is one of the countries whose ranking in Programme for International Students Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) is always at the bottom, students' performance in science has long been drawn the attention of Indonesian researchers. In Indonesia, science is divided into three subjects: physics, chemistry and biology. According to Zulfiani et al. (2014), physics is the most difficult subject in science compared to biology and chemistry, particularly the notion of electricity. The conception of electricity is important to learn, as it is directly related to our daily lives: therefore considering the differences between Indonesian students' conceptions and others' might be a good way to improve students' performance in physics in general. In this case, students' performance in physics is assessed by using diagnostic questions developed by the University of York in 2011. This instrument is used because it has been validated and used in many researches before, so its reliability is certain.

1.2 Purpose of Study

The purpose of the study is the foundation of the research and is the basis of the research questions, methodology and analysis. This study aims to ascertain the common misconceptions held by Indonesian students and compare them with students from other countries for which there are comparable data. In finding the most common misconceptions, it is expected that the study will help teachers and educators to manage those misconceptions in order to support students' learning in science, especially in physics.

The second purpose is to compare the misconceptions held by students in Indonesia with those of students in other countries to see whether there is a difference in the results. Analysing the difference should enable possible contributory factors and the background to the development of the misconception to be established. In this case, it would be helpful in pointing out what could be fixed in a country's science education, as it will indicate how a country can differ from or resemble another.

Finally, after establishing the common misconceptions and the factors affecting them, this study will discuss whether misconception is needed in science learning. The study considers the possibility that misconception is useful for students' learning and discusses whether or not it should be eliminated in learning activities.

1.3 Aim and Discussion of Research Questions

In line with the purpose of this study, explained above, the research questions are set as the basic direction of the research to keep the study on track. The analysis of the results is referred to the research questions and is divided into parts based on the research questions. The research questions of this study are presented below.

(1) What are the common misconceptions about electricity held by Indonesian students?

This question aims to analyse the misconceptions of secondary school students in Indonesia, particularly in the notion of electric circuits. This question is answered by analysing students' answers to online diagnostic questions about electric circuits. The answers are processed by the SPSS programme.

(2) Is there any difference between misconceptions in Indonesia and in other countries in terms of

misconceptions commonly reported in previous research?

This question aims to ascertain the difference between misconceptions held by students in Indonesia and in other countries. It will be answered using a case study to compare the research results for Indonesian students and previous research results presented by other researchers concerning misconceptions about electricity.

1.4 Structure of Study

The report begins with a review of the literature about the level of science education in Indonesia to give a broad view of the education condition in Indonesia which led the researcher to conduct this study. We will then consider misconceptions in science learning as a preliminary stage before discussing the misconceptions to give a basic view of misconceptions in science, especially in physics. Subsequently, we will discuss conceptions about electricity among secondary school students, the sample being secondary school students in Indonesia; this part aims to give a background to the choice of electric circuits as the focus topic in assessing secondary school students' misconceptions. Finally, a brief introduction to the concept of the electric circuit used in the research instrument will be provided before analysing students' answers.

Subsequently, the methodological approach will be discussed, followed by the results of the instrument's validity and reliability from a pilot study. The findings and discussion are then presented. Finally, the research will be concluded, along with implications and recommendations for further research.

Chapter 2 **Literature Review**

2.1 The Level of Science Education in Indonesia

Education has always been a serious concern for every country in the world, especially in Asia. Ordonez and Maclean (2000) stated that education and schooling were receiving more attention from governments in Asia, particularly in less developed countries like Indonesia. As a developing country, Indonesia is still crawling from the bottom place in terms of education ranking among other Asian countries. Indonesia ranked 44th out of 47 countries in TIMSS for international science achievement at 16 years old (Martin et al., 2015), which is based on students' achievement in maths and physics. Referring to only one organisation that assesses education level might be not enough to judge whether a country has a high or low quality of education, however. To get a broader picture of the education level of a country, it is essential to analyse another domains, too. Not too different from TIMSS, PISA uses science as the focus in assessing education. The difference is that TIMSS focuses on achievement in mathematics and science, while PISA focuses on more domains—mathematics and science literacy, reading and problem solving (Klieme, 2016). Therefore, there is a need to consider another platform of assessment such as PISA. Klieme (2016) stated that there is a close correlation between countries' mean scores from TIMSS and PISA. As translated from an Indonesian online newspaper, it is a common stereotype in Indonesia that science has always been considered a subject that determines whether or not a student is clever (Devi, 2016). Using science to define a student's level of intelligence is definitely debatable, but Indonesian people still hold onto that perspective even though it is biased and perhaps unfair for those whose passion is not in the science field. On the other hand, TIMSS and PISA results have a great impact on Indonesian science education. TIMSS showed a relatively low ranking for Indonesia and PISA gave a quite similar result. PISA showed that Indonesia ranked 62nd out of 70 countries for science performance of 15 year old students. Compared to England (rated 15th), Indonesia has very low ranking (OECD, 2016b). These rankings refer to students' achievement, which depends on their understanding in science. This strongly relates to students' conceptions, which Zulfiani et al. (2014) suggest are affected by the learning process—how they are being taught and how the knowledge is being transferred.

Increasing the quality of education in Indonesia is one of the main goals to which the government has paid much attention (OECD, 2016a). The government has been making some efforts to bring education to the next level. In 2008, the government reflected on Malaysia, which was ranked higher in PISA, and tried to change the policy about national exams for the next year by raising standards so that Indonesia could compete with other advanced Asian countries (Kompas, 2008). The policy did not make any change to the education quality at the international level; on the contrary, it attracted criticism from several parties since its implications put more pressure on the students. Another attempt to improve the education quality was made in 2016, when the new minister of education tried to apply the education system of Finland, whose international ranking is high. The full day school which is applied in Finland is seen as a great practice for Indonesian students, as they will be educated in more structured way with character-based education (Firmanto, 2016). This attempt was marked as a failure, however, being cancelled due to opposition from many parties.

Several attempts have been made to solve the problem of education in Indonesia and yet none of them has succeeded in bringing about a significant change. Reflecting on these attempts, something needs to be fixed rather than making a grand breakthrough. As we know, the rankings made by TIMSS and PISA are based on students' performances. Those performances are shown by the scores students achieved during the assessment process for those programmes, not the overall performance of students after the learning process which gradually builds on students' conceptions. Focusing on the policy is a good attempt, but starting with the core problem might be better. As science is the base subject in international assessment, it is essential to ensure that students have the correct conception in science to improve science education in Indonesia.

2.2 Misconception in Science Learning

Science is one of the most challenging subjects in school and students simply have difficulty understanding it (Stein et al., 2008). Those difficulties have been addressed in several ways in research. As mentioned in Eryilmaz (2002), different terms have been used for these difficulties in relation to students' conceptions:

> Novak (1977) called them preconceptions, Driver & Easley (1978) referred to them as alternative conceptions, Helm (1980) called them misconceptions, Sutton (1980) preferred the term children's scientific intuitions, Gilbert, Watts, & Osborne (1982) called them children's science, Halloun and Hestenes (1985) called them common sense concepts, and Pines and West (1986) called them spontaneous knowledge. (p. 1001)

Eryilmaz (2002) has used the term 'preconception' to address all beliefs students have before receiving knowledge and 'misconception' to indicate students' beliefs that contradict accepted scientific theories. In line with Eryilmaz (2002), this research addresses the misconceptions students have in relation to electric circuits, being alternative conceptions from those generally known and accepted based on theory.

The development of students' conceptions need to be considered. Fischler and Lichtfeldt (1992) stated that it is necessary to fix students' misconceptions as early as possible because if the wrong conceptions are long held by students, they will become stronger and more difficult to change. The key here is the learning process, which has a big impact on the conceptions held by students. In fact, in my experience, most of the teachers do not really pay attention to the learning process. As a result of curriculum-based learning in Indonesia, teachers are more focused on enhancing students' scores in every subject without noticing that the way they teach affects students' conception of knowledge. If the learning process is not appropriate, then misconceptions occur. In line with this, Chang et al. (1998) stated that students' learning progress will be hindered by misconceptions. According to Cobern (1993), misconception itself means knowledge that compares poorly with known facts; it is also known as an alternative conception. In their research, Chang et al. (1998) show that there is a correlation between students' achievement and misconceptions. This correlation is also shown by Michelet et al. (2007), who state that misconceptions can be a problem for learning development. However, there are some differences in misconceptions in different countries. Abrahams and Sharpe (2016) stated that there was a big difference in misconceptions in physics between English and Chinese students. As Thijs and Berg (1995) stated, cultural aspects might affect conceptions, even though the influence is limited. In contrast, Bayraktar (2009) found that there was no strong evidence of cultural effect on misconceptions, his research showing that some countries have similar misconceptions in physics. Since there is controversy about how culture and misconception are related, there is a need to ascertain whether any specific factor, such as language or environment, contributes to this issue.

The necessity of researching misconception in science education is that, by ascertaining the common misconceptions held by students, teachers will know which parts of the topic they are failing to transfer to students so that they can find a way to teach it better, as teaching is not only about explaining a conception. Stein et al. (2008) stated that teachers need to be aware of the students' beliefs and their own misconceptions so that the instruction can make a difference in terms of solving the misconception issue in science learning. Furthermore, teachers can proceed to the next level of knowledge more easily as they have knowledge of what kind of misconceptions will occur in their students according to the previous topic. This might also be a warning for the teachers to review their own conceptions. Some researchers have shown that students' misconceptions are probably a result of teachers' misconception. Halim and Meerah (2002) found that the majority of teachers have misconceptions and therefore they are not aware of the students' misconceptions because they consider that their perceptions are correct. If the teachers themselves have misconceptions in some topics of the subject, it means that they transfer incorrect information to the students, which gradually causes wrong conceptions of the knowledge.

2.3 Misconception: Fix it or Leave it?

Much research has been conducted to solve or reduce the existence of misconceptions, as if misconception is something that has to be eliminated—but is misconception really useless? In this section of the study, the advantages and disadvantages of having misconceptions will be discussed to give an insight into how we should treat a misconception—whether we should correct it or let it be. I argue that misconception is an important part of the first stage of students' learning but should be corrected during the learning until students understand the correct conception. This statement will be the basic argument of the discussion.

Hamza and Wickman (2007) discussed the importance of misconception in learning science, in which they stated that misconception could develop reasoning skill. In their research, they found that misconception was not considered an obstacle to future learning by students, but rather as a starting point for them to gain better understanding, leading them to reason through their conceptions. In line with this, Savinainen and Scott (2002) argued that students' misconceptions and difficulties would make the impact of teacher-student dialogue and instruction even stronger; their misconceptions triggered teachers to think sensitively about students' way of thinking.

At this point, we can say that misconception plays an important role in constructing new knowledge, but it needs ultimately to be corrected. However, Halim et al. (2014) stated that it is hard to overcome misconceptions. In their study, they found that students' misconceptions were difficult to change. They stated that students' thinking levels were different, which affects students' ability to understand new concepts; therefore, different treatment should be applied to analyse the change of conception. The difficulty in eliminating misconception is one of the obstacles presented by researchers in relation to students' conceptual knowledge. While Hamza and Wickman (2007) discussed the importance of misconception, Kendeou and Broek (2005), in contrast, were against the idea that misconception is advantageous; they argued that misconception was an intrusive effect on students' memory. However, judging that misconception is not useful for science learning only by referring to the fact that it intrudes upon students' memory is questionable, as science learning should be focusing on how students understand and apply the concepts they have learned in their daily lives, not merely on how they can remember all the concepts. On the other hand, Leach and Scott (2003) strongly argued that seeing misconceptions as incorrect matter should be replaced: they proposed the term 'alternative conception' instead of misconception to represent that students will have different ways of thinking depending on the situation. This represents dynamic thinking in students' minds.

Reflecting on the previous studies and suggestions from researchers mentioned above, I argue that the existence of misconception has its own benefit in science learning. Despite the rejection and efforts to eliminate misconception which have been made in previous studies, misconception creates its own role in building students' knowledge. As Hamza and Wickman (2007) contended, misconception could be the basis for construction of students' new knowledge. Even if misconception is difficult to change (Halim et al., 2014), it plays an important role in helping students develop their reasoning skills, because they will create a reason for their answer as they try to defend their former conception against the new information they receive. However, the aim of learning science is to give students correct knowledge and information; therefore, teaching instruction and the teacher's role are essential in replacing students' misconceptions with the correct ones. In brief, misconception is useful as the foundation for students' early learning, but it needs to be corrected during the process of learning.

2.4 The Conception of Electricity at Secondary Level

It is widely known that physics is a difficult subject in school: most students even see it as the most difficult subject, as it is a combination of theories, concepts and mathematics. Zulfiani et al. (2014) found that there was a relatively high percentage of misconceptions in physics compared to biology and chemistry, the percentage of moderate misconception in physics being 47 per cent, compared to 39 per cent in biology and 40 per cent in chemistry. Zulfiani et al. (2014) stated that misconceptions occur because the teachers do not pay attention to students' preconceptions of physics and give the information as a whole. This issue might also be why students consider physics a difficult subject. In my experience, teachers tend to use the traditional method in teaching physics, making sure that students receive all the materials rather than teaching physics in a way that is easier for students to understand. Since physics has been shown to attract a high proportion of misconceptions, it is essential to focus on each specific topic in physics in efforts to reduce misconceptions. It might be easier to solve wrong conceptions held by students by starting from a narrower discussion of the topic.

Among all the topics in physics, electricity is considered to attract a large degree of misconception, especially on the topic of the electric circuit (Purba & Depari, 2008). This assertion is supported by Zulfiani et al. (2014), who contend in his research that misconceptions found in the topic of electricity are at 36 per cent based on students' test result, the highest percentage of misconceptions among topics. On the other hand, Pesman and Eryilmaz (2010) conducted research on a more focused subtopic, the simple electric circuit. In their research, they stated that common misconceptions about the simple electric circuit (based on other literatures) are the sink model, attenuation model, shared current model, sequential model, clashing current model, empirical rule model, short circuit, power supply as constant current source, parallel circuit, and local reasoning. Research has been conducted into misconceptions about electricity several times all over the world. According to previous research, it is impossible to find a completely similar case of misconception in different countries. Helm (1980) found that students in South Africa commonly have misconceptions about potential difference between two points in a circuit; on the other hand, Shipstone et al. (1988) conducted a study in five European countries (England, France, the Netherlands, Sweden and West Germany) and stated that the difference in misconceptions among those countries is small. The students in England, the Netherlands and Sweden had similar responses to the notion of current consumption: most answered correctly, while the students from France and West Germany got a very low percentage of correct responses. In contrast, French students were the only ones who got a high percentage of correct responses in the notion of voltage in a simple circuit. In Indonesia, as translated from Andriani et al. (2015), students have the most incorrect preconceptions about voltage source before they are given knowledge about electricity. After they receive the material about electricity, they develop more misconceptions about potential difference, even though their misconceptions in both topics are reduced compared to the previous state. These differences from various countries indicate that there are different ways of teaching electricity in each place. The differences might also be a result of referencing researches from too wide a range of year of publication, wherein each researcher conducted and interpreted the case differently.

Chapter 3 **Methodology**

This chapter discusses about the methodology used in the research to analyse the data source, feasibility of the instrument, sample and population. Ethical considerations will also be discussed in this chapter.

3.1 Data Source

The approach used in this research is an online questionnaire due to the distance between the UK and Indonesia, which makes a direct approach extremely difficult. This online instrument in the form of multiple choice questions is used in this research because multiple choice questions are considered to be able to measure any level of cognitive taxonomy, as Downing (2006) presented in the framework for test developers. The author explained twelve steps to develop an effective test instrument, the steps being documented from the results provided by testing standards such as American Educational Research Association (AERA), American Psychological Association (APA), and National Council on Measurement in Education (NCME). An online instrument also makes the time and cost more effective and is easier to use. By using this method, research questions are expected to be answered through analysis of the research results using SPSS 23.0.

Data are obtained from the online questionnaire containing 12 questions about the electric circuit. The instrument is adapted from the diagnostic questions about electric circuits (Key Stage 4) created by the University of York (2011), which were developed from the Evidence-based Practice in Science Education (EPSE) Research Network. The instrument is also developed from questions used by researchers in previous studies (Duit et al., 1985; Shipstone et al., 1988). Millar and Hames (2003) explained that the questions were developed by reviewing the published literature to collect the instruments and revising the questions based on teachers' advice; teachers then used it in their teaching activities and gave a positive response to the instrument, which they found helpful for keeping their teaching on track. They considered it a good resource to diagnose students' conceptions. The questions were then translated into the Indonesian language for Indonesian students. The details of each instrument question are provided in the table below:

Table 1. Instrument questions

No. of Item	Conception
1	Electric current on a series circuit
2	Simple series circuit
3	The relationship between electric current and resistance in series circuit
4	
5	Resistance in parallel circuit
6	The relationship between electric current and resistance in parallel circuit
7	Voltage on parallel circuit and its relationship with resistance
8	
9	Resistance in parallel circuit and its relationship with voltage
10	
11	Voltage on fixed and variable resistor
12	Voltage and electric current on specific point in the series circuit

Data obtained from students' answers will be analysed by using descriptive statistics in SPSS to see the frequencies of choices made by students. The results will answer the first research question—what are the common misconceptions about electricity held by Indonesian students?—by identifying the most frequent misconception for each item. The misconception difference between gender and school type will be analysed by using cross tabulation in SPSS. The discussion there will compare common misconceptions and students' confidence based on school type: this analysis is done by defining the misconception percentage per item and the average of students' confidence in each item. Students' confidence is gained from their assessment of their own confidence as "very confident", "fairly confident", "not confident" or "just guessing", scored as 3, 2, 1 and 0 respectively. The scores are totalled for each school and the percentage presented on graph 3.

The second research question—is there any difference between misconceptions in Indonesia and in other countries in terms of misconceptions commonly reported in previous research?—will be answered by comparing the cumulative answers from those countries with the case study to see whether or not the misconceptions held by students are similar. The possible cause of the differences will be discussed by referring to previous research.

3.2 Feasibility of Instrument

A pilot study is generally conducted before a research takes place: it aims to test the validity and reliability of the instrument used to measure the variable in the research. The instrument is a multiple choice question (MCQ) instrument which has been criticized for only assessing students' memories, not their ability (Quaigrain & Arhin, 2017; Walsh & Seldomridge, 2006); MCQs are considered as giving students an opportunity to guess the answer. Quaigrain and Arhin (2017) are not against the usage of MCQ, however, but encourage researchers to develop an MCQ instrument which focuses on a construction of a reliable instrument with valid measurement. Validity and reliability tests of the instrument are therefore needed.

The pilot study was conducted in an Indonesian vocational school, participants being 30 students consisting of 27 female and three male students. The trial asked the students to complete the online instrument in 30 minutes, observed by teachers to make sure that the students did not open a book or browse the answer via the internet to decrease any external factor that might affect the trial result. The pilot study result was analysed by using Pearson product-moment correlation to assess the validity: correlation coefficients indicate the correlation between each item's score and the total score, the range being from -1 (a perfect negative relationship) to +1 (a perfect positive relationship), in which value of 0 indicates no linear relationship. KR-20 on SPSS 23.0 was also used to detect the reliability of the instrument; the results are presented with Cronbach's alpha coefficient, where the score for high reliability is .70 or more. The level of difficulty per item was also shown to define whether the item is good for measuring the variable or if it should be eliminated to increase the instrument's reliability (Hingorjo & Jaleel, 2012). As the instrument was translated into Indonesian, there might be a lack of clarity, mistakes or wrong interpretations in the translation that affect students' understanding while answering the question; therefore, it is essential to make sure that the instrument is comprehensible. One means of doing this is by conducting a pre-test or pilot study (Maneesriwongul & Dixon, 2004). The trial result is shown in Table 2 below.

Table 2. Instrument's validity

	1a	**1b**	**2a**	**2b**	**3a**	**3b**	**3c**	**4a**	**4b**	**5**	**6a**	**6b**
Pears	.377*	.457*	.193	.240	.223	.392*	.504**	.089	.174	.057	.153	.084

on Correlation												
Sig. (2-tailed)	.040	.011	.306	.202	.237	.032	.004	.641	.357	.765	.419	.661
N	30	30	30	30	30	30	30	30	30	30	30	30

	7	**8a**	**8b**	**8c**	**9**	**10a**	**10b**	**11a**	**11b**	**11c**	**12**	**Total score**
Pearson Correlation	.305	.185	.244	.235	-.004	.334	.478**	.175	.188	.327	.c	1
Sig. (2-tailed)	.101	.328	.194	.212	.982	.072	.008	.354	.320	.078	.	
N	30	30	30	30	30	30	30	30	30	30	30	30

The table above shows the Pearson product-moment (bivariate) correlation coefficient, in which the item is considered valid if the coefficient is less than the coefficient of r_{table} for N= 30 which is 0.361. The table shows that item number 12 is not valid: therefore it needs to be eliminated. Item numbers 1a, 1b, 3b, 3c and 10a have coefficients greater than r_{table}, meaning that these items are valid but need correction. Therefore, the reliability of the items should also be analysed to define which item should be eliminated in order to have a valid and reliable instrument. The reliability of the instrument is presented below.

Table 3. Instrument's reliability

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.278	.279	22

The table above shows that the Cronbach's alpha score for the instrument is 0.278, which means that the reliability is very low because the cut-off score for a reliable instrument is 0.70 (Scholtes et al., 2010). The number of items shown on the table is 22 because item number 12 is automatically removed due to zero variance and very low reliability. According to Hilton and Skrutkowski (2002), using a translated instrument, whether it is translated by a skilled and experienced translator or using a committee approach, usually shows low reliability. An instrument with very low reliability needs to be revised, so the difficulty level and discrimination of the instrument should be analysed to find which item should be fixed and eliminated. This is calculated by "using the formula P=R/T, where P is the item difficulty index, R is the number of correct responses and T is the total number of response" (Mitra et al., 2009: p.3). The results are shown below.

Table 4. Instrument's level of difficulty and discrimination

No	Category	Number of Item	Total Item	Discrimination
1	Easy	1b	1	To be revised
2	Moderate	1a, 2a, 2b, 3a, 3b, 4a, 8a, 8b, 10b,11a	10	Very good
3	Difficult	3c, 4b, 6a, 6b, 8c, 9, 10a, 11b, 11c	9	To be revised
4	Very difficult	5, 7, 12	3	To be discard

The table shows that among 23 items there are ten items with moderate difficulty, which is a sign of a very good item; nine items are categorized as difficult and one item is easy, so the items in both categories need to be revised. In this case, the translation of ten items was changed into different wording which was easier to understand without changing its meaning. The other three items are included in the 'very difficult' category: this means that these items are best discarded. Therefore, the distributed instrument for the official research contains 20 items after revision.

3.3 Sample and Population

The population for this research is all 16–17 year old students in Indonesia, representing second grade high school students. The age limit is used to prevent an over-broad sample which might affect the research result. The sample in Indonesia is second grade students from three different types of school: public school, vocational school and religious school. The total number of students who participated in the research is 64, consisting of 45 female and 19 male students. All participants were asked to fill out the online instrument, the link to which was given by the teacher. In this case, the researcher directly communicated with each physics teacher without any contact with the students. The test lasted around 20 to 30 minutes at the end of a physics lesson. During the test, participants were observed by the teacher to make sure that they did not get the answer from any external source.

3.4 Ethical Considerations

This research has been through research ethics consideration with minimal risk approval submission (see Appendix C) as the study is designed for 16–17 year old students who are in the second grade of high school (Indonesia). As the sample is students, ethical consideration is needed to avoid any potential damage or problem caused by the research in the future. The ethics forms, information for participants and participant consent for the online survey are included in the Appendix (A, B, C).

Participants are informed of the nature and aim of the research through the information section of the online instrument before they proceed to the questionnaire. To participate in the research, participants have to tick all the boxes of items in the information section. By clicking the ‘Next’ button, participants agree to take part in the research and approve all the requirements to be involved in the research.

The data of participants will not be published in the report and participants may choose to be anonymous. Participants provide their gender, date of birth and school information only to make it easier for the researcher to categorize the data without revealing further information.

Chapter 4 **Result and Discussion**

4.1 Research findings and discussion

In this chapter, the results of the research and discussion will be provided in three sections: common misconceptions, school type and gender. Indonesian students' common misconceptions in general will be discussed first. Following this, the differences in misconceptions according to school type and gender will be discussed.

4.1.1. Common misconceptions

Misconceptions in this research, as stated in the literature review, refer to wrong or alternative conceptions held by students compared to the conceptions based on the theory, described in diSessa (2005) as "entrenched false beliefs that needs to be overcome" (p.270). For the analysis, the researcher considered false answers given by students in the test as misconceptions and right answers as correct conceptions. Based on the first research question about the common misconceptions held by Indonesian students, the discussion provided in this part will focus on the general result regardless of students' gender and which school they come from. Research results show the number of true and false answers in the following table.

Table 5. Students' answers

No of Item	True	False
1a	36	28
1b	46	18
2a	20	44
2b	20	44
3a	16	48
3b	11	53
3c	6	58
4a	26	38
4b	19	45
6a	21	43
6b	11	53
8a	18	46
8b	37	27
8c	15	49
9	23	41
10a	22	42
10b	29	35
11a	12	52
11b	13	51
11c	28	36

The score shown in the table above indicates the number of students who have misconceptions for each item, regardless of gender or school type. From the table, it can be seen that item 3c gets the most false answers from students: 58 students of the total of 64 students answered it wrongly. The fewest false answers are for item 1b. Item 3c refers to the relationship between variable resistor and ammeter in a series circuit. On the other hand, the fewest misconceptions are for item 1b. This item refers to electric current in a series circuit.

However, indicating common misconceptions just by defining false answers is questionable, as every student has different conceptions and these might be correct in some cases. A similar case was found in Clerk and Rutherford (2010), one of whose findings was that false positive (FP) answers appeared more often than other misconceptions. False positive was defined as the wrong option chosen by students because for different reasons, not because of a target misconception. The research showed that misconception could not be identified by judging students' false answers alone. Therefore, there is a need to analyse the misconceptions per item to give an insight into view students' misconceptions or alternative conceptions. In the following discussion, students' answers to each item will be presented in terms of frequencies to see the number of students who chose each option.

Item 1

This item is designed to detect understanding of the notion of electric current in a series circuit. The item shows a picture of a series circuit with two ammeters and one motor and asks about the reading on the ammeter. This item consists of two sub-items: the reading of the ammeter and the explanation of the first answer. The table below shows the answers given by students on both sub-items.

Table 6. Students' answers on item 1

	No_1a	Freq	No_1b	Freq
Valid	Exactly 0.4 amps	36	All of the current is used up by the motor.	7
	Less than 0.4 amps, but not zero	16	Some of the current is used up by the motor.	11
	More than 0.4 amps	11	The current is the same everywhere in a series circuit.	46
	Zero	1		

For item 1a, most of the students (36 students) chose the right answer (exactly 0.4 amps), 16 students chose "less than 0.4 amps", 11 students chose "more than 0.4 amps" and one student answered "zero". Similarly, students mostly chose the right answer for item 1b, which is that the electric current is the same at every point on the series circuit; 11 students answered that the current is not the same because it is partly used by the motor and seven students thought that all the current is used by the motor. As the two items are related, we can see why students chose their answers for item 1a and item 1b; even though only 36 students got the correct answer, 46 students had the correct reason. Ten out of 46 students did not choose the correct answer: this shows that students have difficulty applying the concept they know; this might be because their confidence in answering the items is not very high, as the result shows that only 24 students are very confident with their answers, while 33 students are fairly confident, two are not confident, and five are just guessing (see Appendix H). The false answers could also be chosen because students think that the motor uses the current, as 18 students (item 1b) chose it as their reason.

Item 2

This item contains the conception of the voltage effect on a light bulb. This item is also designed to detect whether students are able to build a circuit on their own. The item consists of two sub-items, the first of which defines the ability to check if the circuit is correctly connected. From the table below, it can be seen that most of the students (34 students) chose the wrong answer which states that the bulb is lit and brighter than before, while 20 students answered correctly that the bulb is not lit; the rest of the students chose the "dimmer bulb" and "similar brightness" answer.

Table 7. Students' answers on item 2

	No_2a	Freq	No_2b	Freq
Valid	It is lit – and brighter than before.	34	Current cannot pass through a battery in the wrong direction.	11
	It is lit – but a lot dimmer than bef	5	The bulb is connected to the positive terminal of both batteries, so there is no current through it.	20
	It is lit – similar brightness as bef	5	The two batteries together add to 1.5 V.	1
	It is not lit.	20	The two batteries together add to 4.5 V.	32

Item 2b asks for an explanation of the first answer. The result shows that only students who answered the first sub-item correctly chose the right answer on the second item; 20 students argued that the bulb is not lit due to the wrong formation of batteries. Based on the first item in which students mostly answered wrongly, it is shown in the second item as well that the majority of students (32 students) think that the total voltage is now bigger. In this case, most of the students are confident with their answers (see Appendix H) but they have weak concentration; they are more focused on the batteries, not the circuit arrangement. Based on the reasons they give for item 1b, it is clear that students have good understanding that by adding more batteries the bulb lights brighter. Therefore, the researcher believes that the students have the correct conception about voltage but less thoroughness in analysing the question, rather than it being a misconception.

Item 3

The conception of variable resistor and electric current in a series circuit is defined by item 3. This item consists of three sub-items in which the first and second determine students' understanding of the ammeter reading on an electric current as the effect of variable resistor changes. The result shows that the majority of students chose the wrong answer for item 3a as they thought that the electric current stays the same even after the variable resistor changes. As many as 30 students chose that answer, while another 18 students chose "it gets bigger" and 16 students chose "it gets smaller". Similarly, students mostly answered that the current stays the same for item 3b while the correct answer should be that the current gets smaller because the resistance is increased.

Table 8. Students' answers on item 3

	No_3a	Freq	No_3b	Freq	No_3c	Freq
Valid	It gets bigger.	18	It gets bigger.	18	A large resistance needs more current than a small resistance.	12
	It gets smaller.	16	It gets smaller.	11	Increasing the resistance makes the current smaller after the resistor. It has no effect on the current before the resistor.	8
	It stays the same.	30	It stays the same.	35	Increasing the resistance makes the current smaller after the resistor.	14

	The current before the resistor gets bigger.	
	Increasing the resistance makes the current smaller everywhere in the circuit.	6
	It is the same battery, so it supplies the same current.	24

The table above also shows the result for item 3c, which draws the most misconceptions among the items. Most of the students relate battery use to electric current without considering the change of variable resistor. Only six students answered this sub-item correctly, which shows that this item drew the fewest correct answers from students. Despite the large number of false answers, most students were fairly confident with their answers for item 3 in general (see Appendix H); the reason behind their misconception is shown in item 3c, in which they mostly believed that the current stays the same because the battery is the same. As various answers were chosen by the students, the researcher believes that students lack knowledge on item 3.

Item 4

Item 4 consists of two sub-items which define the concept of resistor usage. The item gives two identical resistors in a series circuit and asks about the ammeter reading of it. This question shows the relationship between resistance and electric current in a series circuit. The table below shows students' choices in answering both sub-items.

Table 9. Students' answers on item 4

	no_4a	Freq	no_4b	Freq
Valid	It drops to zero.	5	It is the same battery, so it supplies the same current.	14
	It gets bigger.	27	The battery cannot push as many charges every second through two resistors.	3
	It gets less, but not zero.	26	The battery is not strong enough to push charges through two resistors.	10
	It stays the same.	6	The current is shared between the two resistors, so each gets half.	19
			Two resistors need	18

	more current than one on its own.	

The number of students who answered it correctly is almost the same as the number of students who had a misconception about this notion: however, the number of students with misconceptions was greater. For item 4b, an explanation of the answer to 4a is demanded. Most students gave the right explanation—that the current is divided into two resistors so it gets less than before, but not zero.

Item 5

Item 5 is eliminated because of its low reliability and high difficulty to increase the reliability of the whole instrument and the opportunity for students to give more correct answers during the test.

Item 6

Like item 4, this item is designed to detect students' conception of the relationship between resistance and electric current, but this item shows the formation of two resistors in a parallel circuit. Like other items, this item consists of two sub-items which ask about the ammeter reading and an explanation of the answer. The table below illustrates students' answers.

Table 10. Students' answers on item 6

no_6a		Freq	**no_6b**	Freq
Valid	It gets bigger.	17	It is still the same battery, so it supplies the same current.	16
	It gets smaller.	26	The current divides at the junction with half going through each resistor. But the ammeter measures	11
	It stays the same.	21	The total resistance is now bigger, so the battery cannot push as big a current round the circuit.	16
			The total resistance is now smaller, because the second resistor provides an extra path for current	21

For item 6a, students are asked to determine the ammeter reading after an identical resistor is added to the parallel circuit. The answer should be that the current stays the same because the ammeter reads the total current after the junction, which is the same as the current before the junction. This item also detects the students' understanding of a parallel circuit. The majority of students had a misconception in this item, as

26 students answered it wrongly. However, the difference between the number of students with false and correct answers is not very significant. As for the explanation for item 4b, the correct answer was chosen less often. Most of the students thought that the current is smaller because it has an extra path to flow from the second resistor; it is clear then that the reason behind their misconception might be that they have less knowledge about the current in a parallel circuit, as only 12 students were guessing and the rest of students had confidence in their wrong conception.

Item 8

After item 6, we go directly to item 8 because the instrument trial showed that item 7 had very low reliability and it was better to discard the item. Therefore, the final instrument did not include item 7. In item 8, there are three sub-items. Items 8a and 8b ask about the reading on the voltmeter in a parallel circuit. The results are shown in the following table.

Table 11. Students' answers on item 8

no_8a	Freq	no_8b	Freq	no_8c	Freq
It gets bigger.	26	It gets bigger.	15	As R increases, the voltage	9

				across it gets bigger (because V=IR). The other voltmeter is across a fi	
It gets smaller.	20	It gets smaller.	12	As R increases, the voltage across it gets bigger (because V=IR). The two voltages have to add to 9V	40
It stays the same.	18	It stays the same.	37	Both resistors are connected directly across the power supply, so the readings on both voltmeters ar	15

This item shows the relationship between resistor and voltage. For item 8a, most students chose that the voltage increases because the resistance in the variable resistor is increased, while the correct answer (the voltage stays the same) gets the most misconceptions. For item 8b, most of the students answered that the voltage on the fixed resistor stays the same, which is correct. On the other hand, for item 8c, which is the explanation of the answers in both item 8a and 8b, the majority of students (40 students) had a misconception. They thought that the total voltage on the parallel circuit should be the same as the voltage of the battery. The inconsistency in answering items 8a and 8b shows that students did not fully understand resistor usage in a parallel circuit. This is supported by the result for item 8c, which shows that students mostly gave a false reason, as 15 students were just guessing the answer and nine students were not confident with their answer.

Item 9

For this item, a different formation was provided to ascertain students' deeper understanding about the relationship between resistance and current, as well as the effect of circuit formation on both variables. Unlike other items, this item demanded students' understanding in calculating the electric current at some points in parallel circuit. The answers are provided in the table below.

Table 12. Students' answers on item 9

	No_9	Frequency
Valid	at a= 100 mA; at b= 50 mA; at c= 50 mA	11
	at a= 200 mA; at b= 100 mA; at c= 100 mA	23
	at a= 200 mA; at b= 200 mA; at c= 0 mA	22
	at a= 400 mA; at b= 200 mA; at c= 200 mA	8

There is a slight difference between the correct answer (23 students)—the current on the parallel circuit is divided into two resistors, making its value half of the value before—and the wrong answer (22 students), that the current on the first resistor in a parallel circuit remains the same as before while on the second resistor it is zero. As there is no significant difference between the students who believed that the current is divided by the branch and those who thought that it is not, the researcher believes that students lack understanding of the notion of current in a parallel circuit. The other false options are chosen because of students' low confidence, as 11 students were just guessing and five were not confident.

Item 10

This item shows another formation of a parallel circuit in which a battery is connected in series to a resistor and ammeter, and students are asked to define the amount of voltage (item 10a) and electric current (10b) after an identical battery is added in parallel to the first battery. The answers for both sub-items are shown below.

Table 13. Students' answers on item 10

no_10a		Frequency	no_10b	Frequency
Valid	0.75 V	19	100 mA	14
	1.5 V	22	200 mA	29
	3 V	20	400 mA	20
	Zero	3	Zero	1

The correct answer for item 10a is 1.5 V, as the battery is connected in parallel: most of the students answered it correctly. Twenty-two students chose the right answer (1.5 V) and 20 students added the second battery to the first so that the total voltage was 3 V, which shows that the degree of misconception about this notion is almost the same as the number of students who gave the correct answer. This might be because students lack understanding of the voltage in a parallel circuit as they add the voltage on each branch. For item 10b, most students chose the correct answer as well, which is 200 mA, while 20 students answered 400 mA which means that they doubled up the current when the battery was doubled too. This is related to item 10a, as students added the voltage and thought that the current should be added up, too. In this case, they understood that voltage is proportional to current, but they failed to apply it on the concept of parallel circuit. Most of the students were very confident (25 students) or fairly confident (24 students) about their answers, which shows that most of the students had high confidence in their misconception.

Item 11

This item consists of three sub-items and contains the conception of voltage in a resistor. Students' understanding of voltage which is connected in parallel to a variable resistor (11a) and a fixed resistor (11b) is tested in this item, while in item 11c, students are asked to define the total voltage if the variable resistor is increased. The following table shows students' answers.

Table 14. Students' answers on item 11

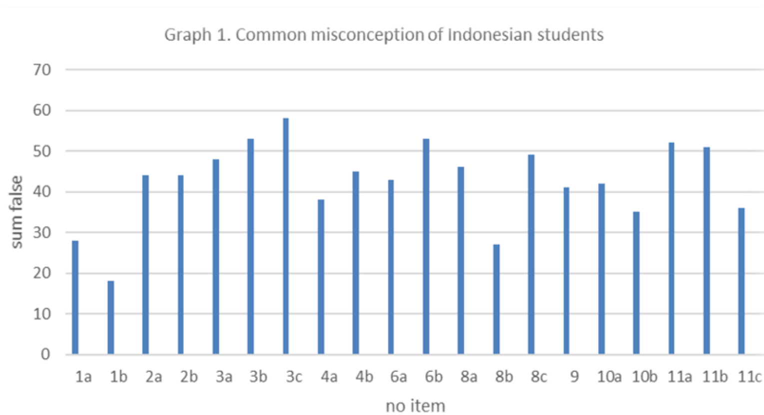
	no_11a	**Freq**	**no_11b**	**Freq**	**no_11 c**	**Freq**
Valid	It gets bigger.	12	It gets bigger.	20	It gets bigger.	25
	It gets smaller.	21	It gets smaller.	13	It gets smalle r.	11
	It stays the same.	31	It stays the same.	31	It stays the same.	28

For item 11a, only 12 students chose the correct answer, which means that most of the students had a misconception about the notion of voltage in a resistor. The majority of students thought that the voltage in both the variable resistor and the fixed resistor (as shown in item 11b) stay the same even after the resistance is increased. Only 13 students got the right answer, which shows that students had a misconception about this item. As for item 11c, the majority of students answered that the total voltage after adding the resistance is the same as before, which shows that students mostly had the correct conception.

Overall, as mentioned before, item 3c attracted the most wrong answers. Item 3c contains the concept of electric current and its relationship with resistance. The question presents a picture of a series circuit consisting of two ammeters and one variable resistor in which students are asked to explain their answer for items 3a and 3b. For this item, they have to determine the ammeter reading before and after the resistor. Based on the theory, the amount of electric current that flows in a series circuit is the same everywhere in the circuit: if a resistor is connected to the circuit and the resistance is increased, then the current will be smaller according to V=IR (Alexander & Sadiku, 2009). The position of the resistor itself—whether it is positioned before or after the ammeter—does not affect the reading on the ammeter because theoretically the electric current in a series circuit is the same at every point of the circuit (Jones et al., 2013), so if the current at one point gets smaller, then the current at other point gets smaller as well.

In this case, most students argued that the current stays the same even after the resistance is increased because the battery used in the circuit is the same as before, so the battery supplies the same amount of electric current. The large number of students who answered wrongly indicates that the majority of students had misconceptions about the relationship between electric current, resistance and voltage (V=IR). However, looking at the large number of false answers given by students, there is also a possibility that they have less knowledge or even no knowledge about this concept. In this case, beginners like secondary school students need to be given practical knowledge about this conception: learning Ohm's law requires a designed method so that the students can acquire the concept correctly before using it at analysis level (McCredden et al., 2016). This might be why students found it difficult to analyse Ohm's law in a question.

A similar case was found in Harsha et al.'s (2015) research: they found that even university students held misconceptions about Ohm's law in which students argued that two identical batteries must behave identically so that the electric current must be the same. The reason for this misconception might be that the students acknowledge that the current at every point in a series circuit is the same. However, they disregard the existence of a variable resistor on the circuit which affects the electric current flow. The main misconception found in this item is that students consider the battery as the source of the electric current, not the source of the voltage. As the students think that electric current depends on the battery only, they consider that the resistance does not affect the electric current, so the reading on the ammeter stays the same after the resistance is increased. They also refer to the equation V=IR to state that the battery whose voltage is constant is directly related to the electric current, so that the electric current is constant as well. In line with this, Cavinato et al. (2017) stated that the common misconception held by students is that they consider a battery as “a source of constant current that is used up by the resistors” (p.7). However, this is not totally wrong. The idea that the electric current is proportional to the voltage is correct if the resistor is fixed (Hutson, 2013). In this case, students need to be informed about how a variable resistor works as well as a fixed resistor. Students need to know that resistance can also change and, if that happens, all variables in the equation V=IR will be affected as well. The graph below shows the number of misconceptions for every item.



From the graph above, a significant decrease is found for item 1b. This signifies the smallest number of misconceptions held by students. This item is basic knowledge about the concept of electric current whose value is always the same at any point in a series circuit (Jones et al., 2013). As most of the students answer this item correctly, it means that students' understanding of this notion is good. However, a few of students still have misconceptions, thinking that the electric current is used up by the motor so that the amount of electric current after the motor is less than that before the motor. This is probably because a few students think that electric current will be decreased after it is used by an element in a circuit. Supporting this result, a similar case was found in Psillos et al. (1987), where it was found that students believed that electric current was consumed by an ammeter. In their research, the authors showed that students had difficulty understanding the functions of elements in a circuit.

In the graph, item 8 shows the most discrepancy between the sub-items: item 8b gets a relatively small number of wrong answers, while items 8a and 8c are almost the same. As we know, every item contains sub-items which are related to each other. Looking at item 8, it shows that students have a misconception about the notion of a resistor. The item provides a picture of a parallel circuit in which a variable resistor and a fixed resistor are connected to two batteries in parallel. Students are asked to define the reading on the voltmeters which are connected to each resistor. Most students are able to determine the reading on the voltmeter which is connected in parallel to a fixed resistor, but they have difficulty determining the voltage reading on a variable resistor. The majority of students say that the voltage increases when the resistance is increased as they relate it to the equation V=IR. Again, students find it hard to apply the concept of resistance when it comes to use of a variable resistor. This is probably because of less explanation and fewer exercises focused on the difference between a variable resistor and a fixed resistor. From item 8c, it also can be seen that most students argue that the voltage on both resistors should add up to 9 V as the amount of voltage on the batteries. In this case, students still have a misconception of the notion of voltage in a parallel circuit. In a parallel circuit, the voltage across each line or branch has the same value; it is the electric current whose value in each line has to be added up to give the total current before the junction.

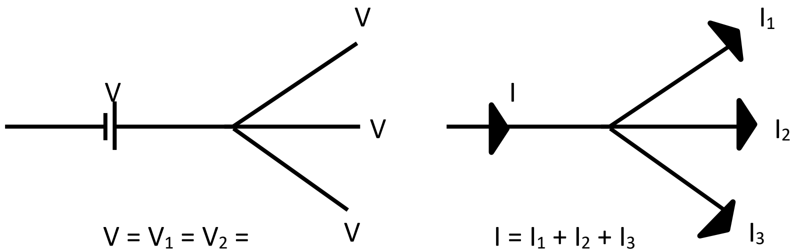


Figure 1. Conception of voltage and current in parallel circuit

4.1.2. School type

Common misconceptions in general were presented in the previous section: however, different misconceptions are also found specifically based on school type. The aim of this analysis is to ascertain if, and what, common misconceptions held by Indonesian students are affected by the school type. The intention is to explain the factors affecting the common misconceptions. Dewi and Suhandi (2016) stated that a possible factor behind students' misconceptions is the lack of learning hours, which is different for each school type. In Indonesia, there are several school types whose differences are marked by the main subject or specialisation to be learnt at the school (Newhouse & Suryadarma, 2009). In this research, three types of school are taken as the sample: religious schools, public schools and vocational schools. Religious school teaches general subjects like other school types, but with more hours dedicated to learning the religious instructions by which students are taught to be engaged in religious and social life, combining general knowledge and Islamic morals (Tan, 2014). In this school, it is compulsory to pray together every time the pray time comes. Students also learn more about religion and its history than any other subject. Of course, physics is also taught in this school, but the time slot for learning physics is less than religious subjects, as stated by the teacher.

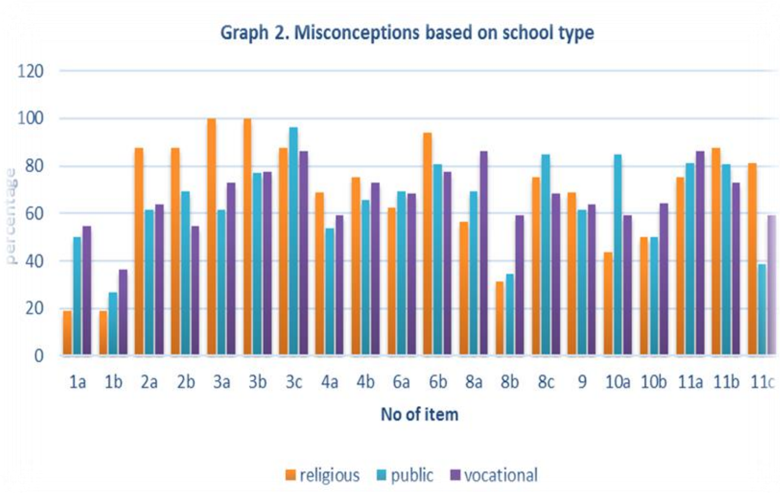
A vocational school is quite similar to a public school but with more practical activities in it. The time slot for physics teaching in the vocational school is two learning hours (2 X 35 minutes) per week. On the other hand, the public school has four learning hours (4 X 45 minutes) per week for physics lessons. The table below presents the percentage of misconceptions held by Indonesian students for every item that they answered based on school type

Table 15. Percentage of misconceptions based on school type

	Percentage of misconceptions		
No of Item	Religious school	Public school	Vocational school
1a	18.8	50	54.5
1b	18.8	26.9	36.4
2a	87.5	61.5	63.6
2b	87.5	69.2	54.5
3a	100	61.5	72.7
3b	100	76.9	77.3
3c	87.5	96.2	86.4
4a	68.8	53.8	59.1
4b	75	65.4	72.7
6a	62.5	69.2	68.2
6b	93.8	80.8	77.3
8a	56.3	69.2	86.4
8b	31.3	34.6	59.1
8c	75	84.6	68.2
9	68.8	61.5	63.6
10a	43.8	84.6	59.1
10b	50	50	64
11a	75	81	86
11b	87.5	80.8	72.7
11c	81.3	38.5	59.1

From the table above, it can be seen that every item shows different misconception held by students from different type of school. For item 1, vocational school students have the most misconceptions compared to other types of school students. On the other hand, items

2, 3 and 4 are dominated by religious school students, who have the largest percentage of misconceptions: 87.5 per cent of religious school students chose false answers to item 2; 98.73 per cent got wrong answers to item 3; and 71.9 per cent chose wrong options for item 4. For item 6, vocational school students have the fewest misconceptions, as their percentage is smaller than other schools. In contrast, religious school students lead on items 8 and 10, as their percentage is the lowest. They held the fewest misconceptions for both items. However, they have the most misconceptions for items 9 and 11. After the test was carried out, the religious school teacher stated that the students had not been properly taught about the concept of the electric circuit because he did not have enough time to deliver the material, as there are several holidays in school that required him to hurry the teaching process in order to finish teaching before the final exam. Having limited time to learn the concept requires students to learn it independently via textbooks. Türkmen and Usta (2007) stated that learning knowledge through textbooks could lead to misconceptions, because students will form their conceptions based on their pre-existing knowledge. This is the most likely explanation for religious school students holding misconceptions, especially on item 3, as seen in the graph below.



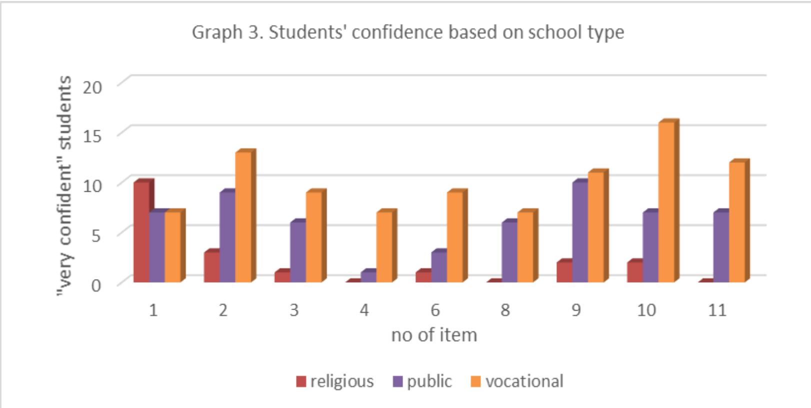
In the graph above, the religious school shows the most fluctuation compared to other schools. For item 1, the religious school has the fewest misconceptions, but for item 3, it has the most. The discrepancy between levels of misconception between one item and another is quite large for religious school students. On the other hand, the vocational school has a more consistent form, wherein the misconceptions for all items range between about 40 per cent and 80 per cent, while public school misconception ranges between 30 per cent and 90 per cent. However, for item 8b, the religious school and the public school show a similar percentage of misconceptions, and so, in relation to the notion of voltage and resistance in a parallel circuit, vocational school students have the most misconceptions. As for item 2, 87.5 per cent of religious school students are more likely to have misconceptions about a simple series circuit in which they are not able to identify the arrangement of a battery in a circuit. This is probably because of the limited time for teacher to deliver the whole curriculum, which caused some topics not to be taught to students.

All types of school show a similar percentage of misconceptions for items 3c, 4, 6a, 9 and 11a. For these five items, three schools show a very close position on the graph. Items 3c and 4 are about the series circuit, which consists of an ammeter and a resistor: the difference is that on item 3c students have to explain the relationship between a variable resistor's resistance and an electric current while item 4 only provides a fixed resistor. As mentioned before, the majority of students from any school had difficulty determining the variable resistor usage in a circuit. The problem is that, at high school level in Indonesia, the concept of resistance is limited to a general resistor without any deep explanation about resistor type. Most students in Indonesia have low recognition of the different effects of different kinds of resistor, as shown in the research result. On the other hand, item 6a shows the parallel circuit of an ammeter and a fixed resistor, and item 9 shows the connection between a voltmeter and a fixed resistor in parallel. Students have similar misconceptions on both items, which means that they have moderate misconception about the parallel connection between the resistor and both the ammeter and the voltmeter.

Item 11a is quite a challenging question, because it provides both a fixed and a variable resistor, which are connected in parallel to the voltmeter. Students from the three school types have similar levels of knowledge about the voltage in the variable resistor, but when it comes to the explanation of their answer, a big gap is found between the types of school students. In the graph, item 11c shows a large difference in percentage for each school, the public school showing the least misconception for this item. Around 38.5 per cent of public school students have misconceptions about the voltage in a resistor, while 59.1 per cent of vocational school students chose the wrong answer. Religious school students have the most misconceptions when explaining their answer, as 81.3 per cent chose the wrong answer. However, as each type of school has different items with misconceptions and the sample is quite small, it is difficult to conclude that school types directly affect students' misconception.

As explained before, the difference between school types is that every school has a different main subject. Religious school heavily emphasises the acknowledgement of religion and the nature of life, while vocational school emphasises the major the school provides. In this research, the chosen vocational school was based in the pharmaceutical field: students are given chemistry knowledge more than physics, as they need it in their main focus subject. Similar to the religious school, the pharmacy school allows limited time for the physics teacher to deliver the whole curriculum, which means that some concepts are not thoroughly explained to the students. However, some physics concepts are related to chemistry, so the misconceptions found in the vocational school are not as many as in the religious school. On the other hand, the public school has quite balanced time allocated to each subject the students learn in school, so the physics teacher in the public school gets more time to deliver and explain insight into the electricity concepts. That might be why public school students show the smallest percentage of misconception in general.

If we relate the percentage of misconception students have to the school performance, it appears that public school students are superior. According to Newhouse and Beegle (2005), public schools in Indonesia are generally considered superior to other school types: in their research, they found that public school students had better performance generally compared to religious school students. However, as mentioned above, linking the misconceptions directly to general school performance is arguable. Therefore, other factors should also be considered. Following the misconceptions based on school type, the instrument also measures the confidence of students while giving their answers to each question. The graph below shows the students' confidence based on school type.



Graph 3 shows the total number of students who answered each question very confidently. It is clearly seen that, on average, high confidence was felt by the vocational school students, while the lowest confidence was shown by the religious school students. A very big gap is presented for item 4, in which vocational students had high confidence in answering the question while public school students showed low confidence; none of the religious school students had high confidence when answering this item. The same pattern is seen for items 6 and 10, in which the confidence of vocational school students was much higher than that of religious and public school students. As for other items, vocational and public school students show smaller discrepancy overall, even though vocational school students lead on all items. In contrast, item 1 shows that religious school students have more confidence than public and religious school students. This might be because religious school students are taught about the concept of electric current in a series circuit more than any other concepts, while vocational school students are more likely to have already learnt all the topics so that they feel high confidence in every question, and they might have been taught the concept of electric current in general more than any other topic in the field of electricity. Vocational students also apply their knowledge in practice, as they have a particular time slot for experiment, so their efficacy is increased, which makes their confidence is higher.

4.1.3 Gender

Other possible causes of misconception need to be recognised to gain a broader view and insight into the analysis of misconceptions in physics. Therefore, it is necessary to check whether gender has a role in increasing students' misconceptions: Temizkan (2003) found in her research that male students had fewer misconceptions than females. On the other hand, Wilson et al. (2016) stated that female students had less physics content and procedural knowledge compared to male students. However, this research does not aim to prove that gender biologically affects misconception; it is more about showing the differences in misconceptions held by students based on gender. The results are shown in the following table.

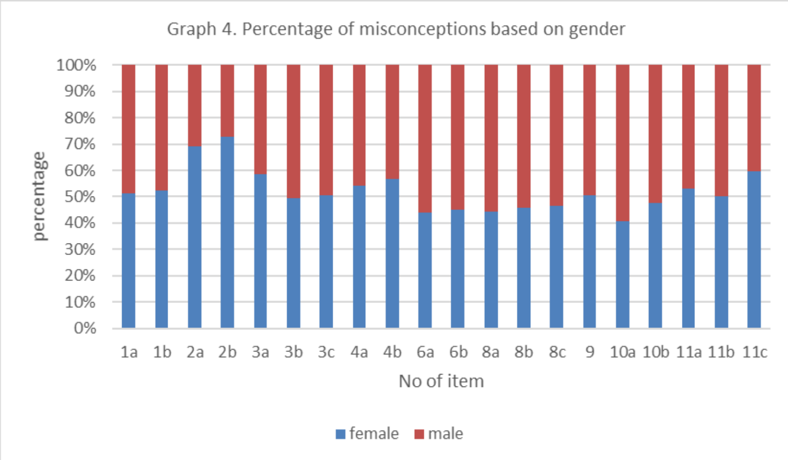
Table 16. Percentage of misconceptions based on gender

	Percentage of misconceptions	
No of Item	**Female**	**Male**
1a	44.4	42.1
1b	28.9	26.3
2a	82.2	36.8
2b	84.4	31.6
3a	82.2	57.9
3b	82.2	84.2
3c	91.1	89.5
4a	62.2	52.6
4b	75.6	57.9
6a	62.2	78.9
6b	77.8	94.7
8a	66.7	84.2
8b	40	47.4
8c	73.3	84.2
9	64.4	63.2

10a	57.8	84.2
10b	53	58
11a	84	74
11b	80	78.9
11c	62.2	42.1

Table 16 above shows that female students have most misconceptions in general compared to male students. Of the 20 items (including sub-items), female students have a larger percentage of misconceptions for 12 items, being items 1, 2, 3, 4, 9 and 11; while male students have more misconceptions on eight items, being items 6, 8 and 10.

In general, the number of male students overall is much smaller than the number of female students, there being 45 females and 19 males. A balance in gender is presented by the public school, where there are 13 female and 13 male students. In the vocational school, there are 16 female students and six male students; while a larger gap is found in the religious school, in which all 16 students are female. The graph below shows the percentage of misconceptions based on gender.

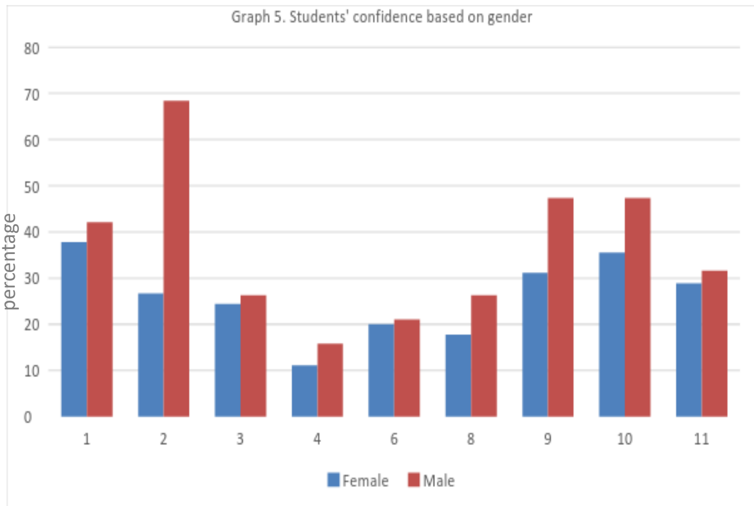


Graph 4 above shows a similar percentage of misconceptions for both genders for items 1, 3b, 3c, 9 and 11b, which means that for these five items there is no difference between female and male students' misconceptions. However, for item 2 there is very large difference between the genders. Item 2 is about the arrangement of a battery in a series circuit. The picture shown in the question represents two batteries which are connected to a bulb, while both positive terminals of both batteries are directly connected to the bulb. In this case, the bulb will not be lit as the electric current does not flow between the positive terminals. For this item, it is shown that male students have a more accurate and rigorous vision in identifying the picture, while female students focus more on the amount of voltage provided by the batteries. Even though this research does not give any statistical result focusing on gender, the differences found in students' misconceptions indicate that male students pay more attention to visible details while female students are more careful about theoretical application. However, this is not conclusive and further tests are needed to explore this suggestion.

Based on the suggested differences in misconceptions, even though it is not conclusive, male students have more misconceptions than female students for item 10a. Item 10a is about the reading on the voltmeter which is connected to two batteries in parallel. Again, in this item male students pay more attention to the picture, as they see that there are two batteries in the circuit so the voltage will be doubled compared to when there is only one battery. The differences show that female students are more likely to focus on the theory, where they learn that the voltage across a parallel circuit has the same value. Even though male students are better at identifying pictures, female students lead on the theoretical knowledge. In line with this, Sencar and

Eryilmaz (2004) found in their research that male students are better in terms of practical knowledge than female students. However, there is a slight difference between this research result and Sencar and Eryilmaz's (2004) argument, in which they stated that there was no difference between male and female students in terms of theoretical knowledge. In their research, they did not control the age of participants, whilst this research limits the age of participants to only 16 and 17 year old students.

The confidence levels of students of both genders is also measured in the instrument, as shown in the graph below.



Graph 5. Students' confidence based on gender

Graph 5 above shows that male students have more confidence in their answers to all the questions. The result is presented in percentages because of the unbalanced number of students. The overall percentage of all items shows lower confidence in female students. Male students have considerably higher confidence in their answers, particularly in item 2 (as seen on graph 5), where the gap between female and male students is very big. This shows that in relation to the concept of the electric current in a series circuit, male students are more likely to be sure of their own knowledge. However, there is unbalanced total number of students for each gender: there were considerably more female students than male students in which it could lead to unequal comparison. Despite the inequality of number of students based on gender, overall results show that male students have fewer misconceptions and higher confidence in the notion of electric circuit in general.

4.2 Difference between Indonesian Students' Misconceptions and Students in Other Countries

From the research results presented in the previous section, it is found that the main misconception held by Indonesian students is in relation to the notion of Ohm's law, particularly the relationship between variable resistor and electric current. However, the most misconceptions were found when students needed to give reasons for their answers, particularly in terms of the relationship between resistance, current and voltage. We can see in Graph 1 that in items 3, 4, 6 and 8, students' misconceptions were higher for the last point of each question: this sub-item was the reasoning for the answers they gave for the previous points in each question. These questions consist of ten points in total, which represents half of the total number of questions. Despite the main misconception, students also had several different conceptions of other specific topics, which are also discussed in detail in the previous section. In this section, the results obtained from the research will be discussed in comparison to other countries to give a general view of the misconceptions held by students in different countries. The discussion in this part will answer the second research question, about the differences in misconceptions found in other countries compared to Indonesia. It is expected that some factors will be found that might influence the difference, as discussed in the next section. The differences in students' misconceptions in several countries will be discussed in the final part of this section. The section refers to several research studies which have been carried out by researchers in similar cases; in every research presented, the results will be compared to the Indonesian results.

The first comparison is between Indonesia and the United States. According to the PISA results from 2015, the United States was in 25th position, which is above the average (OECD, 2016b), while Indonesia has always been on the list of countries whose mean performance in science is below the OECD average. In this case, American students perform better in science than Indonesian students. Gryczka et al. (2016) conducted a research in the United States to show high school students' performance in relation to the electric circuit; the samples were divided into control and experimental groups, which were differentiated by the instruction. In their research, they used an online instrument and found that the students performed well, gaining an average of

70.37 per cent and 70.83 per cent respectively for the two groups, which showed a significant improvement in their performance. In the same year, Yustiandi and Saepuzaman (2016) conducted research in Indonesia to analyse students' performance in the electric circuit and found that the average score gained by students was 57.3 per cent. The two researches showed the difference between the United States and Indonesia; however, the instrument used in the researches was different, even though the types of question given to students were similar. Therefore, we cannot directly compare the results. However, the result does illustrate the students' performance in both countries. On the other hand, Engelhardt and Beichner (2004) tested students' performance in terms of knowledge about the electric circuit by conducting research using multiple choice questions with 454 high school and 681 university students in the United States. The number of participants based on education level is quite unbalanced; however, the result proved that there was no significant difference in misconceptions between them; therefore, the result can be used as a comparison. The research result showed that 28 per cent of students were confused about the conception of current or voltage; students believed that "battery is a constant current source" (p.106).

This case is similar to the result obtained from this research with Indonesian students, in which I found that the majority of students also consider the battery as the source of the electric current. It shows that the main misconception held by American and Indonesian students is generally similar. Gender results also showed similarities: Engelhardt and Beichner (2004) found that American female students had more misconceptions than male students, and Indonesian results also show that male students have fewer misconceptions. Conceptual and gender results from the two researches show similar outcomes, indicating that there are similar misconceptions in American and Indonesian students in relation to the electric circuit.

Referring to the PISA results as the reference for comparing the countries, a general conclusion cannot be drawn by comparing only Indonesia and the United States. Shipstone et al. (1988) conducted a research involving five countries who are above the OECD average in terms of the PISA results. In this case, the results from those five countries will be compared to the Indonesian results. The five countries in the research were England, France, the Netherlands, Sweden and West Germany. The research used multiple choice questions with the following aspects, compared to the Indonesian research.

Table 17. Aspects measured in instrument questions

Aspects			
Shipstone et al (1988)		**Indonesian research**	
Need for a closed circuit (Difference between current and voltage)	Question no. 1	Voltage and electric current on specific point in the series circuit	Question no. 12
Conservation of current in a circuit	Question no. 2 and 6	Electric current in a series circuit	Question no. 1
Causal relationship between current and voltage	Question no. 3		
Flow of charge in a simple circuit	Question no. 4	Simple series circuit	Question no. 2
Phenomenology of simple series and parallel circuits	Question no. 5 and 9		
Voltage and currents in	Question	Resistance in a	Question

a parallel circuit	no. 7	parallel circuit	no. 5
Current in a parallel circuit	Question no. 8		
Distribution of voltages across connecting leads and circuit elements	Question no. 10	Simple series circuit (determining the voltage in series circuit)	Question no. 2
		Voltage on fixed and variable resistor (series circuit)	Question no. 11
Repeated branching of current in a parallel circuit	Question no. 11	Relationship between voltage and resistance in parallel circuit	Question no. 7 – 10
Influence of ordering of components on behaviour of a series circuit (effects of changing resistance values)	Question no. 12	The relationship between electric current and resistance in a series circuit	Question no. 3 and 4
Currents in a parallel circuit (effects of changing resistance values)	Question no. 13	The relationship between electric current and resistance in parallel circuit	Question no. 6

The aspects measured by Shipstone et al. (1988) and this research carried out by me as researcher in Indonesia show some similar elements in the instrument. Although there are differences in some items, the samples and concepts tested in the two researches are identical. Therefore, the research by Shipstone et al. (1988) can be used as comparison. However, the research was conducted almost thirty years ago, so the researcher cannot generalise the results; nevertheless, this research could be a potential comparison, as the scope is wider.

The results in their research are discussed in general, giving no individual data for each country. Shipstone et al. (1988) drew the conclusions generally that the majority of students in all countries, except France, had misconceptions in the notion of voltage in a series circuit. They believed that voltage worked the same as current, wherein the amount of voltage between points in a circuit is identical because the ammeters showed identical values. Shipstone et al. (1988) argued that this misconception occurred because of the teaching method: the concept of voltage was not differentiated from the concept of current. From interviews, they found that students believed that a battery produces a constant current regardless of the circuit it is in.

This result shows similar outcomes to those in Indonesia (in this research) and the United States (Engelhardt & Beichner, 2004), in that students widely believe that a battery is a source of constant current. This misconception leads to students' confusion of the concepts of voltage and current in a circuit (Engelhardt & Beichner, 2004). On the other hand, French students found it hard to differentiate "current" and "energy" because of misunderstanding of the term "current" (Shipstone et al., 1988). The researchers also found that most of the students believed that electric current is consumed by the elements in a circuit: the positioning of elements in a circuit matters for the students, as they think that the current will be reduced if resistance before the bulb is increased; in contrast, if the resistance after the bulb is increased, then nothing will happen to the current. This misconception is also held by Indonesian students, as shown in the research results: the greatest degree of misconception was found for item 3c (Table 4), which asks students to determine the current before and after a variable resistor, where students answered that when the resistance is increased, the current stays the same before the resistor and goes down after the resistor. However, this misconception is still related to students' belief about the conservation of current (Shipstone, 1984).

In brief, the results presented in Shipstone et al. (1988) showed similar misconceptions in Indonesian students to those held by students from England, Germany, the Netherlands, Sweden and France. Reflecting on why these countries are compared—which refers to the education quality ranking provided by PISA and TIMSS—it turns out that students' performance in science cannot be directly related to the misconceptions they have, because several researches have proved that students from top countries have similar conceptions and knowledge to those from low ranked countries.

As the discussion above reveals that there is no significant difference between top ranked countries and low ranked countries in terms of misconceptions about an electric circuit, it is essential to see results from other countries who are in the same category (under the PISA average score), such as Turkey. In this section, the discussion will compare the misconceptions of Indonesian students and students from Turkey and

South Africa. South Africa is not included in the PISA countries and so its rank or quality cannot be compared; however, the researcher chooses to compare South Africa and Indonesia as both countries are now developing, particularly in terms of education.

South African students' performance in the electric circuit was presented in Nkopane et al.'s (2011) research, using an instrument inspired by Shipstone (1988) with 123 students from 17 high schools. The questions given to students were identical to the items used in the research with Indonesian students, in which item no. 2 (in Nkopane et al., 2011) about the light of a bulb after adding a battery in a circuit is similar to item no. 2 in this research. The results showed that only 15 per cent of the South African students answered it correctly, while another 67 per cent got wrong answers and the rest did not answer. Compared to the South African results, Indonesian students have good understanding in analysing that the more batteries used in a series circuit, the more current flows in it, which makes the bulb brighter. However, Indonesian students failed to pay attention to the element instalment in the circuit:

students believed that the bulb is still lit even if the two batteries are connected to the same terminal. Nkopane et al. (2011) found that the most misconceptions found in 12th grade students were about the relationship between resistance and current, wherein students were asked to analyse the brightness of a bulb if the resistance after the bulb is increased. In this case, students had difficulty understanding the concepts based on the position of elements in the circuit. Other findings in the research were that students considered the battery as the source of constant current and that the elements in the circuit could use the electric current flowing through them.

A similar case was presented in the research by Kapartzianis and Kriek (2014) on misconceptions about the electric circuit. The research used the same instrument as Engelhardt and Beichner (2004) with 218 students in Cyprus. The findings showed that the main misconception held by students was that of a weakening current: “the current value decreases as you move through circuit elements until you return to the battery where there is no more current left” (p.310). This misconception relates to the current consumed by elements in a circuit as it flows through, as mentioned before in other research results.

The misconceptions found in both Nkopane et al. (2011) and Kapartzianis and Kriek (2014) have been discussed above. They are found in students from all countries, from Shipstone et al. (1988) up to the most recent research (2017) conducted by the researcher in Indonesia. Therefore, it can be said that the misconceptions about the battery as the constant current source and current being consumed by the circuit elements are common misconceptions among students globally and remain the same even after thirty years. This makes the researcher question what could be the reason behind the unchanging misconceptions throughout the world, and whether they could, or should, be solved.

4.3 Factors affecting Misconceptions

The previous section referred to the aim to analyse some factors influencing the differences in misconceptions held by Indonesian students and those from other countries. In this part, I review published reports to discover those factors, referring to previous researches in similar contexts. By highlighting the factors affecting misconceptions, this research aimed to find a solution to minimising the possibility of students having more misconceptions in the future, particularly in the notion of the electric circuit; however, this is not included in the research, as there is no possibility of drawing a strong conclusion without further tests focusing on this topic. Nevertheless, it is worth considering the possible factors affecting misconceptions to interpret my findings.

As mentioned before, Thijs and Berg (1995) argued that culture has a limited effect on how misconceptions develop in different countries. In line with this, Mesic (2012) agreed that cultural aspects affect misconceptions: in his research, he stated that the difference in culture was the cause of different misconceptions found in Bosnia and Herzegovina and in Slovenia. However, Mesic (2012) referred to the culture of physics education in each country, not the general culture historically held by the country. In contrast, Bayraktar (2009) found no evidence of a causal relationship between culture and misconception as they found similar result on their research compared to the ones done in US and Finland.

Reflecting on these views on culture as a factor influencing misconception, my argument is that culture has no direct relationship with misconceptions held by students. This conclusion arises from the comparison of countries discussed above: the main misconceptions in electric circuits by students from Indonesia, the United States, England, Germany, the Netherlands, Sweden, France, Turkey and South Africa are generally about the battery as the source of constant current and that the current is consumed by circuit elements. This shows that, regardless of culture, misconceptions found in all those different countries throughout the years are similar.

4.3.1 Language

As culture is shown not to be directly related to the misconceptions, I argue that there is a part of culture which could impact how students hold their misconceptions. The part of culture is language. Rollnick (2000) stated that the use of language in science instruction is important: she argued that poor language proficiency in science led to problems mastering the content knowledge. Clerk and Rutherford (2010) conducted a research focusing on the language used in physics, their main argument being that language played an important role in diagnosing misconceptions. In their study, they described in detail how some words used in the questions could cause misconceptions in students, such as use of the word "angle", which was interpreted by students in several ways: the word was meant to be "direction", but students understood it as "turning" (Clerk & Rutherford, 2010). Another word which caused confusion for students was "slightly": the word made students choose the false answer, as Clerk and Rutherford (2010) argued that the word's interpretation was subjective and so depended on the individual. The research showed that a word could be interpreted differently by different students, which in the end could cause misconceptions.

This research uses an instrument which is translated from English into Indonesian. The language used in science is quite complicated to understand and there are some statements which have multiple meanings in

Indonesian. For example, in item 8c, one of the options is "both resistors are connected directly across the power supply"; the word "across" is not used in Indonesian as a physics term: usually when it comes to discussion about the arrangement of elements in a circuit, Indonesian uses "connected to", whether the elements are connected in a series or in parallel form. The instrument's translation is already validated, but the interpretation of the questions and options could be different among the students. This leads to the misconceptions of the students, as a misconception is marked by a wrong answer in this research.

4.3.2 Instruction

Other than language, Başer and Geban (2007) argued that misconceptions occurred after students received instruction; however, the instruction meant here is not the traditional instruction, as they stated that traditional instruction would not affect students' conception. Başer and Geban (2007) explained that the teaching strategy should be developed to establish the correct instruction. They emphasised that the teaching strategy was an important matter to prevent misconceptions. In their research, they found that learning activities using a teaching strategy based on conceptual change could increase students' performance in relation to electricity concepts. The research showed that students' conceptions are affected by how a teacher gives the instruction, so that teaching style might be one of the factors affecting misconceptions.

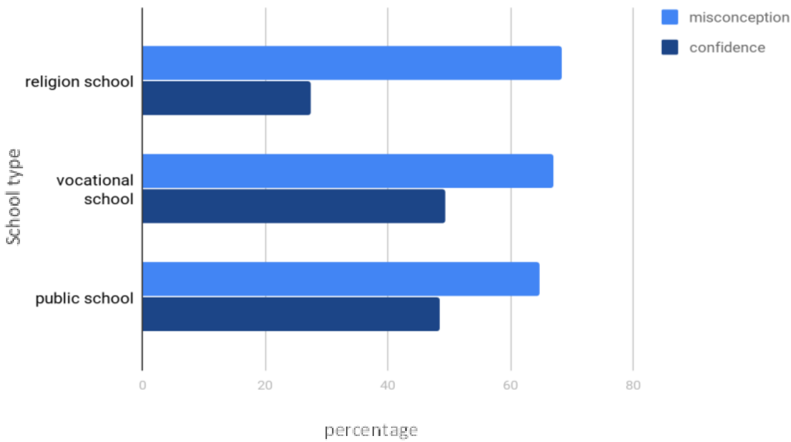
In line with this, Campbell et al. (2016) stated that misconceptions need to be examined and corrected by facilitating students with the right teaching method, so that students can engage in science learning and reduce their misconceptions. Teaching strategies vary depending on the teacher's efficacy. In this research, the sample is students from different school types and those types indicate different styles of teaching and learning. This research shows that there are differences in students' misconceptions based on school type, public school students having the fewest misconceptions compared with students from religious and vocational school. This proves that learning and teaching style have an impact on how students form their conceptions. However, linking the misconceptions to the teaching strategy is questionable, as there are many other factors that might be involved and this research does not show how the teaching strategies in each school are different.

4.3.3 Confidence

Campbell et al.'s (2016) article indirectly relates the solution to misconception to students' science efficacy. Accordingly, I agree that science efficacy, which is represented by students' confidence in this research, plays an important role on students' misconceptions.

Durkin and Rittle-Johnson (2014) stated that "confidence ratings can also reveal whether misconceptions are really being addressed" (p.7). They found that confidence is related to students' conceptual change, as research showed that a reduction in confidence error could increase students' accuracy in answering questions. In this research, I find that religious school students have the lowest confidence compared to others, and the percentage of misconceptions held by religious school students is the highest among students from the three types of school. This shows that students' confidence is related to their misconceptions. The relationship between the two variables is presented in the following graph.

Graph 6. Misconception and confidence based on school type



The graph above shows the average rating of confidence and percentage of misconceptions based on the school type. As can be seen, the confidence ratings for vocational school and public school students are quite similar, whilst the misconception percentage for the vocational school students is greater than for the public school; on the other hand, religious school students' performance shows that they have the largest percentage of misconception and the lowest confidence. Focusing on the religious school students' outcomes, it is shown that the lower the confidence, the more misconceptions are held by students. However, the outcomes from vocational and public school students contradict this hypothesis: vocational school students' confidence is higher than that of public school students, yet they hold a greater number of misconceptions. This might be a result of the learning style, as mentioned before. Vocational students have more practical activities, which makes them remember the concepts through experience and helps them build their confidence through hands-on activities, while public school students learn the theoretical knowledge more than practical. However, they have more time to get explanations from teachers, which helps them to know and understand the concepts more deeply.

4.3.4 Interest and Experience

Other than language, confidence and teaching strategy, students' interests and experience also need to be taken into account. As Sencar and Eryilmaz (2004) found in relation to the difference in students' misconceptions based on gender, they suggested that teachers should pay attention to students' interest and experience, because it affected their conceptions. As mentioned before, the causal relationship between misconception and teaching instruction is proved; however, they found in the research that the mean score for students' interest-experience was 35.2 out of 50 (Sencar & Eryilmaz, 2004), which indicated that the interest factor was more impactful than the teaching instruction itself in terms of students' conceptions, particularly in relation to electricity.

In line with this, Sencar et al. (2001) conducted a research concerning misconceptions about simple electric circuits and found that there was a significant correlation between misconception and students' experience, as they argued that those experiences built students' basic knowledge before they received the knowledge and that basic knowledge acted as the "foundation for the construction of new information" (p.119). However, in this research, students' interests are not measured, though students' experience can be represented by the type of school in which they are studying, given that each school has a different style of science learning. It was mentioned that vocational school students have more practical activities in science compared to religious school students, who have never done any hands-on activity. Linking this to the research results, it shows that religious school students have more misconceptions than those in vocational schools. Compared to both schools, public school students, whose learning hours for physics are longer than other two schools, have the fewest misconceptions, showing the most misconception on only four out of 20 items. Without any statistical test, we cannot conclude this result as a general finding for misconceptions based on interest and experience; however, it shows that a lack of experience in physics could lead to a lack of knowledge or wrong conception about physics.

Chapter 5 **Conclusion, Limitation and Implication**

5.1 Conclusion

In this section, the answers to the research questions will be presented in the concluding discussion based on the findings of this research and published reports on related topics.

As the first research question refers to Indonesian students' common misconceptions, the first conclusion the researcher makes is that Indonesian students, especially those who are in the second grade of high school, have the most misconceptions about the notion of the relationship between the three variables in Ohm's law, which are voltage, current and resistance. Students have difficulty applying their conception of Ohm's law in mathematical problem solving, as in several items they are able to explain the correct concepts, yet they still get false answers for the calculation or the application. As stated in the results and discussion section, they believe that the same battery always provides the same current. The results also show that students' conceptions are different based on school type and gender: school type defines the instruction they receive in learning physics, while gender influences students' confidence and their way of dealing with questions. Based on previous researches, students' conceptions are affected by language, instruction, efficacy, confidence and interest.

The second research question addressed the misconception in Indonesia compared with other countries. The conclusion is that the misconceptions found in Indonesian students in relation to the electric circuit are similar to those found previously by other researchers in other countries. Comparing to other countries' results, which are presented in several published reports, the majority of students globally have a common misconception about how a battery produces a constant current and this misconception has been going on for thirty years. However, as stated in the literature review, researchers tend to see these false conceptions as alternative conceptions rather than misconceptions, as the word 'misconception' connotes a negative meaning, which then leads to negative treatment. Considering it as an alternative conception is more acceptable, as the researcher finds that students' answers do not literally present wrong conceptions: students tend to have a logical reason for every answer they give. Alternative conceptions could help build students' knowledge in terms of the construction of new knowledge they will receive in the future. Therefore, it is essential for teachers to be aware of students' conceptions in order to help them get the most correct conception both theoretically and practically.

5.2 Limitation

Each research question has now been answered by the findings in this research. Nevertheless, there are some limitations to this research which should be corrected in order to give a more reliable and comprehensive report.

There are some old references used in this research which may not wholly support recent discussion about misconception. This is because the amount of research related to misconception has decreased over the years. Most of the recent research related to misconception has been conducted in Turkey, and there are few references to other countries, especially European countries. The comparison between Indonesian and other countries is also a limitation of this research: it would be better if this research were also conducted in other countries to get a more recent and balanced comparison using the same method and instrument. In this case, the researcher tried to conduct the same research in the UK to gain comparable data but was unable to obtain any response. The case study allows the researcher to compare the Indonesian students' results with other countries, yet the instrument used in each research is different. This could cause a gap in the comparison and there could be other external factors causing inequality in the comparison.

The research results have generally answered the points which the researcher intended to address, but there is a lack of data to provide a more insightful discussion. As the researcher has decided to consider misconception as alternative conception, there is a need to conduct interviews to discover more about students' knowledge and reasoning skills to explain the alternative reasons for which students give their answers. Even though the instrument in this research allows the researcher to acknowledge the students' reasons for each answer, the options provided in the instrument could limit the students' freedom in constructing their reasons. Moreover, the sample size used in this research is quite small and so cannot fully represent all students in Indonesia.

5.3 Recommendation

This research provides information about major misconceptions in the notion of the electric circuit and factors which potentially form the background of those misconceptions. The findings could contribute to improve teachers' awareness of students' misconceptions and so help teachers find the most appropriate method to deal with them. The study also could contribute to an improvement in physics education in Indonesia, as the research compares the results with other countries which top the global education ranking.

As the findings provide some information about misconceptions based on school type and gender, the researcher considers that this could be a potential topic for further research. It could be useful in helping Indonesian schools manage the curriculum to produce a better outcome for students' performance in physics, or in science generally. It also could be a reference for teachers to plan their instruction, particularly in teaching the electric circuit, based on students' gender. Without discriminating, teachers could provide a balanced instruction to give equal support for all students. However, as stated in the limitations, the researcher recommends that further research provides an interview section to strengthen the argument and deepen the discussion.

Lastly, the researcher finds that there is little research focusing on misconception in Indonesia. Educators and researchers are more likely to emphasise the teaching model or instrument development as the main focus of research without taking students' misconception into account. Students' misconception is the first thing to be considered, as it is the basis of the construction of students' knowledge: if this is missed, then the teaching model and instrument cannot perfectly improve students' learning outcomes. Therefore, the researcher recommends that more research be carried out to solve or reduce misconception in both students and teachers in any field as part of the effort to improve education quality in Indonesia.

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