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# Analyzing students' conceptions in simple electric circuits topic using four-tier diagnostic test

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**Abstract:** The research was conducted to analyze the level of students' conceptions, common misconceptions of students, and to compare the misconceptions between female and male students. This study uses a survey research design. This study involved 207 students with 94 male and 113 female students from five schools in Bandung and Cimahi City, West Bandung, West Java Province, Indonesia. The results showed 35.8% of students at the level of lack of knowledge, 30.6% misconception, 6.8% false negative, 15.2% false positive, and 11.6% scientific knowledge. Students' misconceptions are considered significant because they show >10% of all subtopics, especially in sub-topic parallel series. Based on the analysis, men and women don't have significant differences in misconceptions. It's better for further research to pay more attention to the participants, which students who can take the test seriously.

**Keywords:** Four-tier diagnostic test, misconception, simple electric circuit, students' conception

**Abstrak:** Riset dilakukan untuk menganalisis level konsepsi, miskonsepsi umum siswa, dan membandingkan miskonsepsi diantara siswa perempuan dan laki-laki. Penelitian ini menggunakan desain penelitian survei. Penelitian ini melibatkan 207 siswa yang terdiri dari 113 perempuan dan 94 laki-laki dari lima sekolah di Kota Bandung dan Cimahi, Kabupaten Bandung Barat, Provinsi Jawa Barat, Indonesia. Hasil penelitian menunjukkan 35,8% siswa berada pada tingkat pengetahuan kurang, 30,6% miskonsepsi, 6,8% false negative, 15,2% false positif, dan 11,6% pengetahuan ilmiah. Miskonsepsi siswa dianggap signifikan karena menunjukkan >10% dari seluruh subtopik, terutama pada subtopik seri paralel. Berdasarkan analisis, laki-laki dan perempuan tidak memiliki perbedaan miskonsepsi yang signifikan. Sebaiknya bagi penelitian selanjutnya untuk lebih memperhatikan pesertanya, yaitu siswa yang dapat mengikuti ujian dengan serius.

**Kata kunci:** Tes diagnostik empat tingkat, miskonsepsi, rangkaian listrik sederhana, konsepsi siswa



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## INTRODUCTION

Physics lessons are a branch of scientific knowledge about the events that occur in everyday life, both those that can be observed indirectly and directly. Physics also studies various concepts and theories about how a scientific event can occur, whether it is easy or difficult to understand (Sani et al., 2019). Learning physics requires a high level of concentration and basic knowledge because each concept must be accurate and should not deviate. In physics, there are more laws that are constant and continuous, so students who want to learn physics must be precise in referring to the concepts they use; otherwise, they may misunderstand the subject (Susilowati et al., 2020).

Physics teaching still lacks attention to students' preconceptions. Teachers tend to assume that students do not have initial concepts or preconceptions and immediately provide material without first asking what concepts the students know. Misconceptions that occur in students are caused by the delivery of concepts or facts detached by the teacher, so students receive incomplete concepts or become confused. The use of teaching methods that do not correspond to the objectives of the material being taught causes students to receive different concepts from the intended ones. Teachers tend to use methods that involve students less actively; most teachers only use lecture methods, and students only listen. Misconceptions can also occur in the reference books used; these books present incomplete concepts or use other concepts that students may find difficult to explain or define. Generally, books only present generalizations without considering exceptions, causing teachers to doubt in explaining the concepts in the books (Suprapto, 2020).

Misconceptions in learning can be defined as a student's misunderstanding when receiving knowledge transfer during learning. According to Resbiantoro et al. (2022) misconceptions are alternative concepts obtained by students when they make mistakes in the learning process. The misconceptions believed by students become barriers to learning. Other research also adds that if a misconception is allowed and ingrained in a student's understanding, it will have negative effects on the student. According to Chen et al. (2020) in their research that students will experience frustration in learning because they maintain incorrect concepts, and their expectations will be disrupted. This has a negative impact on students' psychological well-being. Students become reluctant to cultivate their curiosity and lack confidence to learn further, leading to a reluctance to receive further education due to perceived difficulties.

Misunderstandings caused by misconceptions of a concept will affect students' ability to apply the learning material, this is because misunderstandings can cause differences in understanding between students' knowledge and scientific or expert knowledge (Sari & Mufit, 2023). Students will have difficulty understanding subsequent concepts, which will continue until they experience saturation in learning (Nasir et al., 2024). It is feared that students who are trapped in misconceptions will have poor and sustained learning outcomes (Yuberti et al., 2020). Learning misconceptions are common and have an impact on students' attitudes toward academics, such as problem-solving skills. Misconceptions significantly affect learning in various disciplines, such as science, mathematics, and engineering technology (Liu & Fang, 2016).

The four-tier test has been employed by researchers to ascertain the extent of student misconceptions, particularly in the field of physics. The four-tier test is an extension of the three-tier test results. Compared to other diagnostic tests for misconceptions, the advantages of the four-tier test include the ability to differentiate student confidence levels based on their reasons, allowing for an understanding of students' basic concepts. Furthermore, it can be used to diagnose misconceptions more comprehensively, as it has four levels to explore conceptual understanding. It can be used in various science-related topics and reduce students' misconceptions. Research using the four-tier test aims to facilitate teachers in evaluating their teaching techniques with students (Yuberti et al., 2020).

Previous research conducted by Soeharto et al. (2019) stated that diagnostic tests using the four-tier test could identify students' misconceptions, with 33.06% experiencing misconceptions in science subjects. This research is expected to help teachers in teaching at schools and researchers who intend to research misconceptions of students in science. According to other research, three primary processes are suggested before carrying out future research on diagnostic tests for students' misconceptions: examining the concepts that usually lead to misconceptions in students, choosing diagnostic test instruments based on their strengths and weaknesses, and using two or more combinations of instruments to improve the quality of the research. Additional translated information from the original text requires a proper source (Soeharto et al., 2019).

The selection of the four-tier test as a solution to identify students' misconceptions has proven to be more effective than using other methods such as questionnaires, interviews, and regular multiple-choice tests. Although each diagnostic test to determine students' misconceptions has its limitations and advantages, researchers have assessed that the four-tier test is more effective. The limitation of the four-tier test is that it must ensure that the test questions are always reliable because they have a high level of sensitivity in implanting concepts (Yuberti et al., 2020).

The significance of comprehending students' misconceptions regarding basic electrical circuits has been underscored by prior research, but little has focused on differences in misconceptions between male and female students. According to Wilson et al. (2016) found in physical learning that female students had a better understanding of physics and procedures compared to male students. Temizkan (2003) strengthened these findings by finding that male students had lower misconceptions compared to female students. The two statements above give rise to the assumption that the misconception between women and men is different, especially in studying Physics.

A significant amount of research has been conducted on the use of four-tier tests to assess students' understanding of Physics in various topics. These topics include geometrical optics (Kaltakci-Gurel et al., 2017), work and energy (Samsudin et al., 2021), simple machine (Yuberti et al., 2020), force and vibration (Kaniawati et al., 2021), mechanical wave (Tumanggor et al., 2020), Newton's laws (Kaniawati et al., 2019), heat and temperature (Fenditasari et al., 2020). The majority of the research on basic electricity circuit topics was conducted using two-tier and three-tier tests. Open-ended questions and Semi-structured interview questions for diagnosing students' conception (Ivanjek et al., 2021; Mellu & Baok, 2020; Moodley & Gaigher, 2019; Urban, 2017). However, relatively few studies have concentrated on this subject using a four-tier test. Other fields besides physics, such as biology (Karakate et al., 2018; Zhao et al., 2023) and chemistry conceptions (Agung et al., 2024; Dewi et al., 2020; Habiddin & Page, 2019; Laliyo et al., 2021), has been used to diagnose student misconceptions using four-tier.

However, the difference between the research to be conducted and previous research is that it focuses on simple electrical circuit topics in physics, which is part of dynamic electricity. The topic is complex and abstract, so students may experience difficulties understanding the basic concepts of electrical circuits. Therefore, research on student misconceptions about simple electrical circuits is fundamental to understanding and overcoming the student's misconceptions. In the future, students will have the correct concepts to use in various electrical applications (Hidayat et al., 2023; Setyani et al., 2017). This research also uses the four-tier diagnostic test to focus on students' misconceptions about the topic. While the previous research is still in development and uses three-tier tests (Peşman, 2010). The study will be conducted in several schools in the city of Bandung. By identifying students' misconceptions in the simple electrical circuits topics, this research aims to contribute to sustainable efforts in science education to improve teaching practices and enhance students' conceptual understanding. Ultimately, through this identification of misconceptions, we can more accurately assess the extent of learning outcomes and provide information on which topics need more emphasis in teaching practices. This research was carried out to analyze students' conceptions level and common misconceptions and compare the female and male students' misconceptions.

## METHOD

### Research design and participant

The research design utilized in this study is quantitative survey research. Unlike experimental research, there is no intervention or treatment provided by the researcher to the participants (Creswell, 2013). The main objective of this research is to assess students' understanding of simple electric circuit topics. The focus is on describing their conceptions as they are, without any attempts to change or manipulate them. The survey data is collected at a specific point in time, following a cross-sectional design (Fraenkel et al., 2012).

The participants selected for this study share a common characteristic, which is that they have already received education on simple electric circuit topics as part of the 2013 National Curriculum. The research was conducted in West Bandung, Bandung and Cimahi City, West Java Province, Indonesia. The target population for this study was 9th-grade students. A total of 207 students participated in the research, with ages ranging from 14 to 15 years old. These participants were selected from a combination of two private schools and three public schools. The sampling method employed in this research was convenience sampling, whereby participants were chosen based on their availability for the study. The distribution of participants can be observed in Table 1.

Table 1. The distribution of participants

| Gender | Number of Students | Percentages (%) |
|---|---|---|
| Male | 94 | 45.4 |
| Female | 113 | 54,6 |
| Total | 207 | 100 |

### Research instrument

In this study, the data were obtained using a four-layer test on a simple electrical circuit and distributed offline to samples using paper. A four-level diagnostic test on the topic of simple electricity was developed by several researchers. The research instrument was adopted from Peşman and Eryilmaz's (2010) article. This article was published in 2010 in "The Journal of Educational Research," and the instrument has met validity and reliability. In this article, there are 12 sets of questions that are still in the form of a three-tier test. In the research conducted, the three-tier question form available in the article was modified into a four-tier test with the addition of a fourth level, namely the confidence level in answers for reasons at the third level of questions (Peşman & Eryilmaz, 2010).

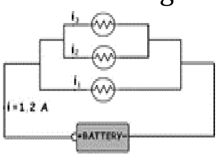
For the question to be valid, tiers one and three must both be valid (Caleon & Subramaniam, 2010). A comparatively low average score was determined to be 2.93 (Standar Deviasi = 2.35) out of a possible 12. This shows that the diagnostic exam for simple electric circuits was tough, which is consistent with the degrees of difficulty seen for all items other than Item 7. The majority of the objects had a difficulty level below 0.40, with a mean of 0.24 (Standar Deviasi = 0.14).

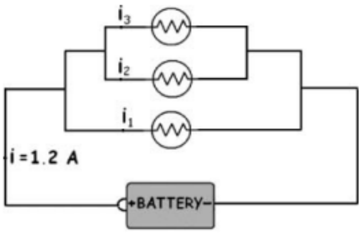
To evaluate how each item related to the overall score, point-biserial coefficients were computed. Item 2 was the only item with point-biserial coefficients below 0.20, with an average of 0.46. These coefficients are typically regarded as acceptable (Beichner, 1994).

The reliability of the simple electric circuit diagnostic test was assessed using Cronbach's alpha coefficient, which was found to be 0.69. This indicates moderate internal consistency reliability. When Item 2 was excluded, the reliability coefficient increased to 0.75, suggesting that this item may have had less relevance to the construct being measured.

In the context of a diagnostic measure such as a simple electric circuit diagnostic test, where the aim is to identify students' misconceptions, generally accepted validity and reliability are more important than achieving very high levels of validity and reliability. Therefore, based on these tables and explanations, a simple electric circuit diagnostic test can be considered valid and reliable in measuring students' misconceptions about simple electrical circuits. The sample of three tier test is shown in Figure 1 and four-tier tests modification on simple electric circuits is shown in Table 2.

Table 2. The sample four-tier tests modification on simple electric circuits

| No | Tier | Question |
|---|---|---|
| 2 | 1 | Look at the figure below!<br><br>Figure 2<br>The current at the main branch is 1.2 A. What are the magnitudes of currents I1, I2, and I3?<br>a. 0.6/0.3/0.3<br>b. 0.4/0.4/0.4 |
| | 2 | Are you sure about your answers given to the previous two questions?<br>a. Sure<br>b. Not Sure |
| | 3 | Which one of the following is the reason for your answer to the previous question?<br>a. After the current is divided evenly on the first junction, it is again divided evenly on the second junction.<br>b. Because the identical bulbs are in parallel, currents with the same magnitude pass through the bulbs.<br>c. ……………………………………………………………………………………………<br>…………………………………………………………………………………………… |
| | 4 | Are you sure about your answers given to the previous two questions?<br>a. Sure<br>b. Not Sure |




2.1. The current at the main branch is 1.2 A. What are the magnitudes of currents $i_1$, $i_2$, and $i_3$?
   a) 0.6/0.3/0.3
   b) 0.4/0.4/0.4
2.2. Which one of the followings is the reason of your answer to the previous question?
   a) After the current is divided evenly on the first junction, it is again divided evenly on the second junction.
   b) Because the identical bulbs are in parallel, currents with the same magnitude pass through the bulbs.
   c) ..........................................................................................................
   ..........................................................................................................
2.3. Are you sure about your answers given to the previous two questions?
   a) Sure.
   b) Not sure.

Fig. 1. The sample of three tier test on simple electric circuit

**Data analysis**

The research data that has been collected is analyzed, namely categorizing each answer to the question, namely SK = scientific knowledge, LK = lack of knowledge, M = misconception, FN = false negative, and FP = false positive (Kiray & Simsek, 2021). The combination answer and decision of four-tier test is shown in Table 3.

Data analysis was carried out using Excel and SPSS 25 programs, taking into account the probabilities outlined in Table 3. Each category, such as scientific knowledge, false positives, false negatives, misconception, and lack of knowledge, was coded based on specific answer patterns in the four-level test.

For scientific knowledge, the code "SK" is given if students answer correctly at the first and third levels and are confident at the second and fourth levels (1-1-1-1). Similarly, false-positive responses were coded "FP" when a correct answer was given at the first level, an incorrect one on the third level, and confidence was expressed at the second and fourth levels (1-1-0-1). If an incorrect was given at the first level, a correct answer was given at the third level, and confidence was expressed at the second and fourth levels (0-1-1-1), it is in the false negative (FN) category. If a wrong answer is given at the first level, a belief is stated at the second level, a wrong answer is given at the third level, and a belief is stated at the fourth level (0-1-0-1), then it is in the misconceptions (M) category. LK was assigned to sequences not characterized by SK, FP, FN, and M.

Table 3. Category decisions for answer combinations on a four-tier test

| 1st Tier | 2nd Tier | 3rd Tier | 4th Tier | Decision |
|---|---|---|---|---|
| True | Sure | False | Sure | FP |
| True | Sure | True | Sure | SK |
| False | Sure | False | Sure | M |
| False | Sure | True | Sure | FN |
| True | Not Sure | True | Not Sure | LK |

| | | | | |
|---|---|---|---|---|
| True | Sure | True | Not Sure | LK |
| True | Not Sure | False | Sure | LK |
| True | Not Sure | True | Sure | LK |
| True | Sure | False | Not Sure | LK |
| True | Not Sure | False | Not Sure | LK |
| False | Not Sure | True | Sure | LK |
| False | Sure | True | Not Sure | LK |
| False | Sure | False | Not Sure | LK |
| False | Not Sure | True | Not Sure | LK |
| False | Not Sure | False | Not Sure | LK |
| False | Not Sure | False | Sure | LK |

## RESULTS AND DISCUSSION

### Level of students' conception on simple electric circuit topic

From data analysis, the result and discussion were displayed simultaneously. the result of students' conception level on simple electric circuit topics shown in Figure 1 including the categories of SK, FN, FB, M, and LK. The results of students' conception level shown in Figure 2.

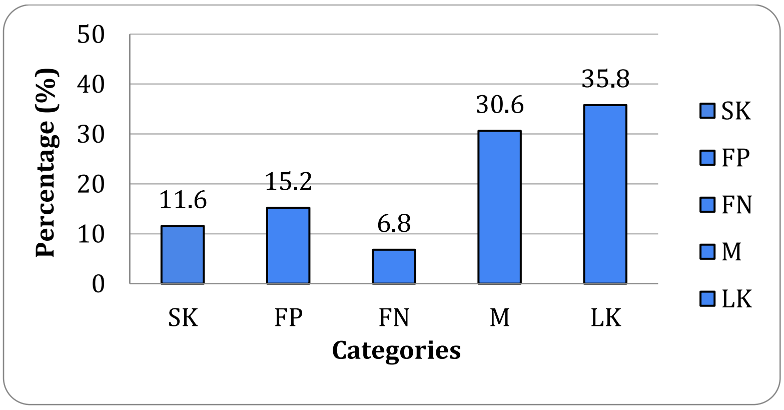



Fig. 2. Percentages of students' conception on simple electric circuit

The results revealed 35.8% of students are at lack of knowledge level, 30.6% misconception, 6.8% false negative, 15.2% false positive, 11.6% scientific knowledge. It showed that students have a low level of scientific understanding and high level of lack of knowledge and misconceptions in simple electric circuit topics. It can be caused by various reasons. One reason is that the conventional learning model used in science education tends to be dominated by teachers and relies on lectures, questions and answers, and assignments. This can cause students to become passive and result in low understanding of science material. To address this issue, educators must adopt an empirical approach to science education, such as utilizing video as a medium for science instruction (Kusuma & Arifin, 2021). Another possible reason is lack of confidence and overconfidence in students' knowledge in a particular domain, which may indicate that such knowledge is frequently used, rarely questioned or checked against other criteria, and can be defended even in the presence of explicit counter-evidence (Saglam, 2015). In addition, students' difficulties in understanding statistical calculations can also lead to a low level of their scientific understanding (Arismika et al., 2020). Therefore, teachers need to use interesting methods to teach students, and students need to be motivated and encouraged to learn (Nasir et al., 2023).

To have a better view of students' conception, the analysis is then carried on deeper by analyzing students' conception for five subtopics. These subtopics consist of Current, Kirchhoff law, Power, Resistance in series and parallel circuit. The results show a diverse percentage for each category of students' conceptions. The analysis results can be seen in Table 4.

Table 4. Percentages of students' conception on each subtopic in a simple electric circuit

| **Sub topic** | **Categories** | | | | |
|---|---|---|---|---|---|
| | **SK(%)** | **FP(%)** | **FN(%)** | **M(%)** | **LK(%)** |
| Current | 12,1 | 24,6 | 0,2 | 39,4 | 23,7 |
| Kirchhoff law | 9,5 | 17,3 | 9,9 | 23,3 | 40,0 |
| Power | 18,4 | 10,1 | 4,1 | 37,0 | 30,4 |
| Resistance in series circuit | 19,8 | 6,8 | 9,7 | 17,9 | 45,9 |
| Resistance in parallel circuit | 1,0 | 2,4 | 3,9 | 57,5 | 35,3 |

The first subtopic is about electric current. In this subtopic, students are expected to have a correct understanding of the shape of an electric circuit that can carry current. The highest percentage of students' understanding level for this subtopic is Misconception with an average percentage of 39.4%. This sub-topic has a slightly lower percentage of Scientific Knowledge than Misconceptions. The percentage of scientific understanding for this subtopic is 12.1%. The low scientific knowledge of students and the high level of misconceptions about current in simple electric circuits can be caused by several reasons. For example, the use of learning methods that are not suitable for learning objectives, learning methods that focus on the teacher (teacher center) will make students passive in class and have difficulty understanding physics concepts. In Addition, students are the source of misconceptions who experience associations of thoughts, humanistic thinking, errors in intuition, incomplete reasoning, and imperfect cognitive development (Sholihat et al., 2017)

The second sub topic is Kirchoff's law, in this subtopic students are expected to have an understanding of how to calculate the amount of current flowing on a branch in a parallel circuit, compare the amount of current in a series circuit, compare the amount of current at a point in a series circuit and parallel circuit, and compare the magnitude of the current at several points in a parallel circuit. The highest percentage of students' wrong understanding for this subtopic was lack of knowledge with an average percentage of 40.0%, followed by misconceptions of 23.3% with an average percentage of wrong understanding considered significant (<10%). The percentage of Scientific Knowledge from this subtopic is 9.5%. The low scientific knowledge of students and the high level of erroneous understanding of

Kirchoff's law in simple electrical circuits can be caused by several reasons based on several previous studies, including because students have difficulty understanding concepts, the inability of students in mathematical calculations and students who have difficulty converting units (Rusilowati et al., 2006). In another study, the cause of misconceptions about Kirchoff's legal material was due to students' lack of thoroughness in writing symbols and units and not understanding the formulas used (Rahmat et al., 2017).

The third sub topic is about power, in this subtopic students are expected to have an understanding of how current relates to bulb brightness in series and parallel circuits. The highest percentage in this subtopic is Misconception with a value of 37.0%, followed by Lack of Knowledge with 30.4%. Then, the percentage of Scientific Knowledge from this subtopic is higher than the other subtopics, namely 18.4%. This happens because the power sub-material is an abstract material because it involves micro phenomena in everyday life, the application of the electric power sub-material is also related to everyday life. Therefore, to understand the concept of the electric power subtopic, it requires the help of learning media such as videos (Yusal, 2022).

The fourth subtopic is about resistance in series circuit, in this subtopic students are expected to understand the relationship between the magnitude of different resistances and the current that affects the brightness of the bulb. The highest percentage in this subtopic is Lack of Knowledge with a large percentage of 45.9% of the five categories. Then, for misconceptions, the percentage is 17.9%, which is smaller than the percentage of all subtopics. Then, Scientific Knowledge is also in the highest order compared to other sub-topics with a percentage of 19.8%. Based on previous research, students' difficulties in learning series obstacle course material were caused by the students themselves having learning difficulties and supported by teaching factors which made students tend to be more passive when learning (Nofitasari & Sihombing, 2017).

The fifth subtopic is about resistance in parallel circuits, in this subtopic students are expected to have a good understanding of the relationship between current and bulb brightness. The highest percentage for this subtopic is Misconception with a value of 57.3% and then Lack of Knowledge with a value of 35.5%. Then for the percentage of Scientific Knowledge, which is 1.0%, it is low compared to other subtopics. The low scientific knowledge is caused by the low competence of students in interpreting data in questions (Sulsilah et al., 2019). In other research, the parallel barriers sub-topic needs to involve several concepts that make this subtopic difficult to understand, this is the reason why in this subtopic students experience very high misconceptions and lack of knowledge (Perdana et al., 2018).

The findings of this study indicate that the highest percentages among the five subtopics are attributed to misconceptions and a lack of knowledge. Upon analyzing these results, it becomes evident that students are uncertain about their answers or unable to provide a proper explanation even when they choose the correct option. The same trend can be observed in the analysis of misconceptions. Participants attempted to justify their choices using expressions that did not involve misconceptions or displayed uncertainty in their responses. This situation can be attributed to a lack of knowledge or scientific errors, rather than the participants having conceptual misconceptions (Atasoy & Ergin, 2017)

Based on the findings of several studies, it has been proposed that utilizing four-tier tests instead of traditional multiple-choice tests can be more effective in various aspects.

These tests are believed to be better at identifying students' misconceptions, pinpointing incorrect answers that arise from a lack of knowledge, and identifying students who lack confidence in their responses. Additionally, they can also highlight correct answers that may have been the result of lucky guesses, thus providing a more accurate assessment of students' understanding (Kaltakci-Gurel et al., 2017; Kiray & Simsek, 2021; Zhao et al., 2023). By incorporating these tests into education, educators can gain a better understanding of students' misconceptions and provide targeted support to address them.

**Most common students' misconception on simple electric circuit topic**

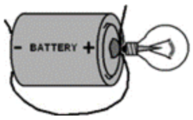
The researchers compared the misconception scores of students using different numbers of tiers in their tests: only the first tier (conventional multiple-choice test), the first and third tiers (two-tier test), and all four-tiers. The comparison was conducted for 12 predetermined misconceptions. The prevalence of misconceptions among students was exaggerated by both the one-tier and two-tier assessments, as evidenced by the mean percentages analysis. Nevertheless, the four-tier test was more precise in identifying the precise percentages of misconceptions that pupils possessed. Despite the absence of any misconceptions, it was observed that certain students provided inaccurate responses in the first tier. This may be due to a dearth of knowledge or false negatives. Therefore, unlike the two-tier and three-tier tests, the four-tier tests were capable of effectively assessing misconceptions without the interference of errors or knowledge gaps (Kaltakci-Gurel et al., 2017). The comparison in percentage of students' misconceptions on simple electric circuit topics is presented in Table 5.

Table 5. Comparison percentages of students'

| Question | Only First Tier | First and Third Tier | Four Tier | Misconception (>20.7%) |
|---|---|---|---|---|
| Q1 | 26,1 | 24,2 | 17,9 | - |
| Q2 | 66,2 | 44,4 | 32,4 | Misconception |
| Q3 | 53,6 | 25,6 | 13,0 | - |
| Q4 | 59,4 | 41,5 | 21,7 | Misconception |
| Q5 | 65,7 | 62,8 | 43,5 | Misconception |
| Q6 | 34,3 | 23,7 | 15,5 | - |
| Q7 | 44,4 | 30,4 | 28,5 | Misconception |
| Q8 | 66,7 | 55,6 | 45,4 | Misconception |
| Q9 | 52,7 | 30,4 | 17,9 | - |
| Q10 | 78,7 | 77,8 | 60,9 | Misconception |
| Q11 | 49,3 | 32,4 | 13,5 | - |
| Q12 | 90,3 | 82,6 | 57,5 | Misconception |
| Mean | 57,3 | 44,3 | 30,6 | |

In order for a misconception to be deemed significant, it must be present in at least ten percent of the sample (Caleon & Subramaniam, 2010). Following the meticulous examination of the percentages of each misconception for the four-tier test results of misconceptions scores, as illustrated in Table 5, students have misconceptions in seven of the questions (Q2, Q4, Q5, Q7, Q8, Q10, Q12) with a percentage of 21.7% or exceeding. These significant misconceptions are found in every concept of simple electric circuit topic. The biggest percentage of misconception is 60.9% in Q10. The question that has a big percentage shown in Table 6.

Table 6. The most common misconception question in simple electric circuit topic

| No | Tier | Question |
|---|---|---|
| 1 | 1 | Look at the figure below!<br><br><br>Will the bulb in Figure 11 light??<br>a. Yes, it will.<br>b. No, it will not. |
| | 2 | Are you sure about your answers given to the previous two questions?<br>c. Sure<br>d. Not Sure |
| | 3 | Which one of the following is the reason for your answer to the previous question?<br>a. + and – charges are able to meet in the bulb because the bulb touches the positive and negative terminals.<br>b. The bulb is connected to the positive terminal.<br>c. Electric current passes through the bulb.<br>d. Electric current does not pass through the bulb.<br>e. ………………………………………………………………………………………… |
| | 4 | Are you sure about your answers given to the previous two questions?<br>c. Sure<br>d. Not Sure |

Based on the search results, it seems that the question is about misconceptions that students have regarding a circuit with a light bulb. According to the search results, many students answer that the light bulb will turn on, when in fact it will not turn on. This is because the light bulb is only attached to the positive pole of the battery and is not connected to the wire, so the current cannot pass through the light. In another research on misconceptions in learning physics, it was stated that the cause of many students experiencing misconceptions was because students had not fulfilled the initial concept of electric circuits and light bulbs. In addition, the stage of cognitive development which only relies on intuition and preconceptions (Syahrul et al., 2015)

Based on an analysis of the review of the factors that cause misconceptions in electrical physics material, it is divided into two, namely mostly student factors and teacher factors. Teachers who do not master concepts well and have poor relationships with students. Apart from that, the learning resources and teaching materials used by teachers and students also have the potential to cause conceptual errors (Nurulwati et al., 2014)

**Students' misconception based on gender**

In this study, a comparison was made of the percentage of misconceptions between male and female students at four different levels. To be classified as a misconception, students must believe the wrong conception but remain confident in their answer. In other words, if students give wrong answers at the first and third levels, but are confident at the second and fourth levels, they will get a misconception score. Figure x shows a comparison of the percentage of misconceptions between male and female students on the topic of simple electrical circuits. The percentages of students' conceptions according to gender is shown in Figure 3.

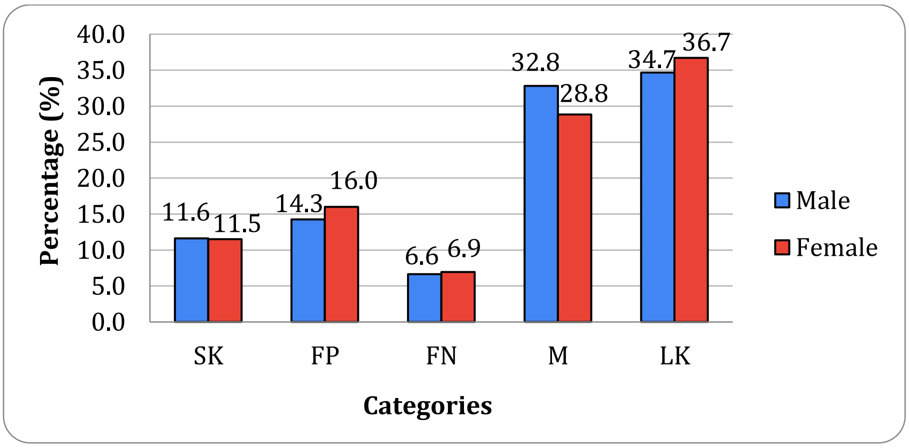



Fig. 3. Percentages of students' conceptions according to gender

In the comparison between male and female students, there is the highest difference in the level of misconceptions with a percentage difference of 4.0%. The next percentage difference is 2.0% for lack of knowledge and 1.7% for false positives. For the last two levels, namely false negative and scientific knowledge, there is a smaller percentage difference, below 1%. The difference in the percentage of false negatives is only 0.3%, while for scientific knowledge it is only 0.1%. Therefore, the highest percentage difference is at the level of misconception, while the lowest percentage difference is at the scientific knowledge level.

In this research data, the Kolmogorov-Smirnov normality test was carried out which showed that the data were not normally distributed with a significance value of less than 0.05, namely 0.00 for males and 0.01 for females. Then a difference test was carried out to determine whether there was a significant difference in the level of misconceptions between male students and female students. From this test, the Asymp. results were obtained. Sig. (2-tailed) < 0.05, namely 0.068, which means there is no significant difference in the level of misconceptions between male and female students. The results of the significance of misconception based on gender are shown in Table 7

Table 7. Significance of misconception based on gender

| | Misconception value |
|---|---|
| Mann-Whitney U | 4537.000 |
| Z | -1.824 |
| Asymp. Sig. (2-tailed) | 0.068 |

This finding is consistent with previous research which stated that there is no gender difference when it comes to math and science. This study concluded that boys and girls have the same psychological traits and cognitive abilities. Even for complex problem solving, which is an essential skill in science, technology, engineering, and math careers, there are no significant gender differences at the primary or secondary school level (Hyde & Linn, 2006). In addition, data from the National Assessment of Educational Progress (NAEP) in 2005 showed that gender similarities in science achievement were stronger than gender differences. To analyze misconceptions, the percentage of misconceptions of male and female students continues to be studied for each concept separately. A comparison of the percentage of misconceptions between male and female students for 5 subtopics in simple electrical circuits shown in Table 8.

Table 8. Gender-specific percentages of students' conceptions regarding each subtopic

| Sub topic | Question number | Male (%) | Female (%) |
|---|---|---|---|
| Current | M1 | 13,8 | 25,5 |
| | M10 | 59,6 | 74,5 |
| Mean | | 36,7 | 50,0 |
| Kirchhoff law | M2 | 37,2 | 34,0 |
| | M3 | 9,6 | 19,1 |
| | M4 | 25,5 | 22,3 |
| | M5 | 51,1 | 44,7 |
| | M6 | 18,1 | 16,0 |
| | M11 | 16,0 | 13,8 |
| Mean | | 26,2 | 23,2 |
| Power | M7 | 30,9 | 31,9 |
| | M8 | 48,9 | 51,1 |
| Mean | | 39,9 | 41,5 |
| Resistance circuit in series | M9 | 19,1 | 20,2 |
| Mean | | 19,1 | 20,2 |
| Resistance circuit in parallel | M12 | 63,8 | 62,8 |
| Mean | | 63,8 | 62,8 |

Differences in misconceptions between male and female students in simple electric circuit material varied for each sub-topic. The sub-topic that showed the highest difference in misconceptions was Current, with a percentage difference of 13%. Meanwhile, the lowest percentage difference occurred in the resistance circuit in parallel subtopic, with a difference of 1.0%. Nonetheless, both male and female students had the highest misconceptions on the resistance circuit in parallel sub-topic, with an average percentage of 63.8% and 62.8%, respectively. This represents a percentage difference of 1%. In contrast, the lowest percentage of misconceptions among male and female students occurred in the resistance circuit in series sub-topic, with respective percentages of 19.1% and 20.2%. The percentage difference is only 1.1%.

In general, male students had a slightly higher percentage of misconceptions than female students for all subtopics in simple electric circuits. However, this difference is not significant. This finding is in line with previous research which investigated the effect of gender on the level of misconceptions in physics learning. The study concluded that male students tend to be more susceptible to misconceptions than female students (Ali, 2019) Factors such as a better understanding of mathematical concepts for female students and a higher level of activity among male students can explain this difference, so that male students are more prone to having misconceptions when studying.

Through this research we can find out how well students understand simple electrical circuits and whether there are differences between female and male students in this understanding. By using a four-level instrument developed from previous research, we can understand students' understanding more deeply, especially in terms of recognizing specific understanding errors. This helps teachers to better design appropriate ways of teaching. However, the use of more detailed instruments can also make data analysis more complicated and difficult to interpret the results. However, the results of this research can provide more complete information about student understanding, which can ultimately help improve the quality of science learning by improving student understanding. In addition, we can also better understand the differences between female and male students in comprehension errors, which can help in designing better, more inclusive curricula and teaching methods.

## CONCLUSION

Based on the findings and discussion in the previous chapters, the use of the four-level test has provided valuable information about students' conceptions of the topic of simple electric circuits. Overall, 35.8% of grade IX students were at the Lack of Knowledge level, 30.6% had misconceptions, 15.2% showed false positives, 11.6% had scientific knowledge, and 6.8% experienced false negatives. The highest level of conception is lack of knowledge, which confirms that the four-level test is more accurate in calculating the percentage of students' misconceptions on the topic of simple electric circuits. This test can effectively assess misconceptions that are not caused by mistakes or lack of knowledge. Of the five levels of conception, students tend to have more misconceptions than scientific knowledge. In the five subtopics studied, students had the highest level of misconceptions and scientific knowledge in the Resistance in parallel circuit subtopics. This can be caused by the low competence of students in interpreting the data in the questions and the difficulty level of this subtopic which involves several concepts.

The misconceptions experienced by students are considered significant in all simple electric circuit concepts, as shown by the percentage of student misconceptions that exceed 10%. The further conclusion of this study is that overall, male students have a higher percentage of conceptions than female students at four levels including misconceptions. Misconceptions are more common in male students than female students. Although there was a mean percentage difference between the two groups, this difference was not significant in terms of misconceptions.

Future research should be concerned with determining the right strategy to help correct the misconceptions identified in this research. The next researcher can investigate the factors that influence students' confidence in the misconceptions that may exist in their knowledge. In addition, research can involve other variables such as scientific reasoning ability and extend the research sample to other school levels, not just junior high school.

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