



Diagnostic Analysis of Direct Current Electricity Misconceptions: A Two-Tiered Assessment of Grade XII Students

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Abstract

This study aims to analyze the misconceptions of grade XII student of SMA Kemala Bhayangkari 1 Kubu Raya using an Aiken-validated two-tier diagnostic test. Direct Current Electricity concepts like current, voltage, and resistance are frequently misunderstood due to their abstract nature. Results indicate a moderate level of misconceptions (45.60%), with the highest error found in series-parallel circuits (68.52%), where students tend to ignore circuit topology when calculating resistance. This study contributes to physics education by pinpointing specific cognitive barriers in circuit analysis, which is critical for mastering advanced electrodynamics. The findings provide a diagnostic foundation for developing targeted remedial strategies such as inquiry-based simulations to bridge the gap between student mental models and scientific reality.

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INTRODUCTION

Physics is a branch of science that studies various objects in nature along with the phenomena, events and interactions that occur in these objects (Riska Dwi Anggraini et al., 2022). Physics is often expressed in the form of concepts, laws, and theories derived from observations, measurements, and scientific reasoning. Essentially, in studying physics, students are required not only to master formulas and calculations but also to understand the concepts and their interrelationships that underlie various natural phenomena.

Brand et al. (2025) states that before learning a new idea or concept, including knowledge, beliefs, skills, attitudes, social and cultural experiences, a person will use that prior knowledge to understand and construct new knowledge. This conception developed during pre-learning is called initial conception or preconception (Ibrahim, 2019:40). In general, individuals have different preconceptions about the new concepts they learn. A person's preconceptions may be correct, but it's also not uncommon for someone to have incorrect preconceptions, leading to misconceptions.

Misconceptions in physics learning are a common problem among students. Misconceptions are understandings that are inconsistent with expert concepts. According to Suparno (2013:7), misconceptions can be defined as concepts understood by someone but contradict actual scientific concepts. In the context of physics learning, misconceptions often arise because students incorrectly associate everyday experiences with scientific concepts, or because the teacher's presentation and learning resources are unclear (Ibrahim & Suparno, 2018:55). In general, the difficulties experienced by students in physics are often caused by abstract material concepts that are difficult to grasp with logical thinking (Mboniyivuze et al., 2022).

Unlike standard multiple-choice test, a two-tier diagnostic instrument allows for a deeper distinction between lack of knowledge and deep-rooted misconceptions by requiring students to justify their primary answers. This approach is essential for facilitating "conceptual change", where educators must first expose student's pre-existing mental models before aligning them with scientific laws. Current global research suggests that misconceptions in electricity often stem from "threshold concepts" that, if misunderstood, prevent further progress in physics.

One of the abstract physics topics that makes it difficult for students to understand is direct current electricity. This statement aligns with the results of interviews conducted by researchers with Physics teachers at SMA Kemala Bhayangkari 1 Kubu Raya, who stated that electricity is indeed very difficult for students to understand due to its abstract nature. Furthermore, students often experience difficulties in understanding the relationship between voltage, current, and resistance, as well as the application of Ohm's law in circuits.

One method for identifying student misconceptions is to use a multiple-choice, reasoned misconception test. A multiple-choice, reasoned misconception test is a type of multiple-choice question, but it is equipped with open-ended reasons so that students are still allowed to express their reasons in depth (Suparno, 2010: 59-83). Research related to

misconceptions in direct current electricity generally still focuses on general identification without elaborating on misconceptions in specific sub concepts that are most susceptible to misunderstanding. Therefore, this study will map in detail student misconceptions in the concepts of series-parallel circuits, equivalent resistance, the relationship between current, voltage, and resistance. These findings are expected to form the basis for developing more targeted physics learning strategies at SMA Kemala Bhayangkari 1 Kubu Raya in the material of Direct Current Electricity using a misconception test instrument Two-tier.

METHOD

Research Design

This research is descriptive with a quantitative approach. Quantitative descriptive research is a type of research used to analyze data by explaining or presenting collected data based on real-world conditions (Djafar et al., 2024). Descriptive research involves presenting conclusions or information through statistical presentation. Meanwhile, quantitative research methods are applied to examine predetermined populations and samples by collecting data through research instruments and analyzing data using a quantitative or statistical approach (Sugiyono, 2014).

Population and Sample

This research was conducted at Kemala Bhayangkari 1 High School, Kubu Raya. The population in this study were 12th grade high school students who had studied direct current electricity. The sampling in this study used the Purposive Sampling technique. According to Sugiyono (2022), Purposive Sampling is a sampling technique with certain considerations. The sample selection in this study refers to the recommendations of physics teachers at Kemala Bhayangkari 1 High School, Kubu Raya, so the selected sample was 54 students in grades XII C and XII F.

Data Collection and Instrument

The data collection technique in this study used a two-tier misconception test in the form of a multiple-choice written test with open-ended reasons consisting of 8 questions. two-tier is a type of question that has two levels, where the first level contains questions, while the second level contains a choice of reasons related to the answers at the first level (Hairunnisa et al., 2023). The questions used in this study are the result of an adaptation of the instrument developed by Halim et al. (2024). Based on the research findings, it can be concluded that the research instrument is in the form of a questionnaire two-tier multiple choice the developed method is suitable for use and meets the criteria with an average Aiken validation result of 1 which is classified as high criteria.

The percentage of students according to Rahayu et al. (2023) In answering the test questions, they are grouped into 3 categories, namely understanding the concept, not understanding the concept, and misconceptions as in Table 1.

Table 1. Student Answer Categories

Answer Type	Category
Wrong answer and wrong reason	Don't Understand the Concept
Correct answer and wrong reason	Misconception
Wrong answers and correct reasons	
Correct answer and correct reason	Understand the Concept

Data Analysis

Data analysis in this study was conducted to assess students' level of understanding of various direct current electricity concepts and to determine the categories of student responses: understanding the concept, not understanding the concept, and misconceptions. Data were obtained from the results of a misconception two-tier test in the form of open-ended multiple-choice questions which include eight questions.

In the first stage, the analysis was conducted by grouping each student's answers based on predetermined categories. The frequency of each response was then calculated across all students. Next, the percentage of each category within each question was analyzed to identify misconceptions regarding each DC electrical concept, including Ohm's law, series circuits, parallel circuits, and series-parallel combinations. The percentage results from the eight questions were then averaged to obtain a general overview of the students' level of understanding.

Furthermore, analysis was conducted to identify the concepts that most frequently cause misconceptions. This step aims to determine the level of student understanding. However, data interpretation focuses not only on the percentage of misconceptions but also on the reasons given by students to identify patterns of conceptual errors that occur. Thus, the overall results of the data analysis provide an overview of the distribution of students' conceptual understanding and misconceptions, which can be used as a basis for recommending more appropriate learning strategies to reduce misconceptions in direct current electricity material.

RESULT AND DISCUSSION

Based on the results of the misconception test analysis, we can identify the concepts in direct current electricity that most frequently cause misconceptions among students. This finding is evident in the percentage of misconceptions for each concept presented. This percentage indicates the level of student understanding of the material being tested. Details of the question aspects for each question can be seen in Table 2.

Table 2. Aspects of Direct Current Electricity Problems

Question	Question Aspect
1	Ohm's Law
2	Series Network
3	Parallel Circuit
4	Series & Parallel Circuits

Question	Question Aspect
5	Ohm's Law
6	Parallel Circuit
7	Series Network
8	Series & Parallel Circuits

The analysis results show that the majority of students are in the misconception category with an average percentage of 45.60%. A total of 28.01% are in the concept understanding category, while the other 26.39% are included in the concept not understanding category. These results indicate that the majority of students still experience errors in understanding the concept of direct current electricity, although some students have a correct understanding. The percentage of answers to each question item according to its category can be seen in Table 3.

Table 3. Percentage of Answers to Each Question According to Category

Question	Criteria					
	Misconception		Understand the Concept		Don't Understand the Concept	
	F	%	F	%	F	%
1	21	38,89	18	33,33	15	27,78
2	23	42,59	24	44,44	7	12,96
3	22	40,74	22	40,74	10	18,52
4	37	68,52	10	18,52	7	12,96
5	26	48,15	11	20,37	17	31,48
6	24	44,44	7	12,96	23	42,59
7	25	46,30	19	35,19	10	18,52
8	19	35,19	10	18,52	25	46,30
Amount	365		224,1		211,1	
Average	45,60		28,01		26,39	

Information:

F = Frequency of Number of Students

% = Percentage of Criteria

Based on the percentage of the research results, it shows that the highest category of misconceptions is in question number 4 at 68.52%. The misconception in this question is known that students assume that electrical resistances are always added without considering whether the circuit is series or parallel. As a result, they do not understand that a parallel arrangement produces a smaller equivalent resistance than a series arrangement, so that a series arrangement produces a larger equivalent resistance (Hartanto & Nawir, 2018).

The next high percentage of misconceptions is found in question number 5, at 48.15%. Students assume that the current will not double when the voltage is doubled at a fixed resistance. This indicates a misconception among students that voltage and current are inversely proportional, even though voltage and current are directly proportional according to Ohm's law (Pujayanto et al., 2022). Meanwhile, in question number 7, the

misconception obtained was 46,30%, Students often fail to understand that in a series circuit, the current is divided according to the resistance, while the voltage is the same across each resistor. Similarly, question number 6, which received 44.44% of student misconceptions, related to the relationship between resistance and current in a parallel circuit. This indicates that students have weaknesses in understanding the mathematical relationship concept in Ohm's law.

In questions 2 and 3, the percentages were 42.59% and 40.74% respectively. In question 2, some students did not understand that the current remains constant in a series circuit and the voltage is divided based on the resistance of each resistor. Meanwhile, in question number 3, students do not understand that in a parallel circuit, the voltage remains the same in each branch, while the current will vary according to the resistance of each resistor. Similarly, in question number 1, where 38.89% of misconceptions were obtained, students experienced misconceptions regarding the concept of the value of current strength, if the value of resistance or electrical voltage is changed. Students do not deeply understand the relationship between current, voltage, and resistance according to Ohm's Law. Based on the misconceptions experienced by students, it can be stated that students do not deeply understand the relationship between current, voltage, and resistance according to Ohm's Law both when applied to series and parallel circuits (Halim et al., 2024).

Furthermore, a misconception occurred in question number 8, amounting to 35.19%, where students assumed that a series circuit has a greater equivalent resistance than a parallel circuit when two resistors of the same value are used. Furthermore, misunderstandings of Ohm's Law and the principles of current and voltage division are among the main causes of recurring misconceptions in various question contexts. The high misconception rate in series-parallel combinations (68.52%) suggests a "reductionist" mental model where students treat all resistors as a single linear sequence. This failure to visualize the "current split" at junctions indicates that students prioritize algebraic summation over the spatial-logical understanding of circuit topology. To address this, simulations and "Predict-Observe-Explain (POE)" models are recommended to make the invisible flow of current visible.

This finding indicates the need for learning strategies that place more emphasis on conceptual understanding, not just mathematical calculations (Ferli Yanti & Wijaya, 2023). For example, the use of electrical circuit simulation media, laboratory experiments, and inquiry-based approaches can help students directly observe how current, resistance, and voltage function in various types of circuits. This is in line with research by Aktaş & Karamustafaoğlu. (2024), which states that the use of simulation media, laboratory experiments, and inquiry-based approaches has been proven to help students directly observe how current, resistance, and voltage work in various circuit conditions. This research shows that direct approaches such as simulations and experiments not only improve understanding but also specifically reduce certain misconceptions. Thus, students can build a deeper understanding and reduce common misconceptions about the concept of direct current electricity.

CONCLUSION

This study confirms that misconceptions in DC electricity remain a significant barrier, with an average rate of 45.60%. To mitigate these issues globally, physics curricula should shift from formula-centric teaching to diagnostic-driven remediation. Specifically, the integration of Virtual Labs and inquiry-based models is essential to provide students with the empirical experiences needed to rectify abstract misconceptions. The highest misconceptions were found in the concept of series and parallel circuits, especially related to the understanding of equivalent resistance, division of current and voltage, and the application of Ohm's Law. These findings indicate that students have not mastered the basic concepts thoroughly and still misinterpret the relationship between current, voltage, and resistance. Factors causing misconceptions include the abstract nature of the material and students' lack of experience in observing electrical phenomena directly.

This study was limited by a relatively small number of questions and the use of a single instrument. Therefore, future research is recommended to use more comprehensive instruments and incorporate experimental or simulation-based learning approaches to strengthen students' conceptual understanding. More interactive learning strategies like predict observe explain (POE), inquiry-based learning, and the use of virtual lab can be applied to help students build conceptual relationships more concretely and systematically.

The findings of this study contribute to physics education by emphasizing the importance of identifying misconceptions as a basis for designing more effective learning. Furthermore, the results can serve as a reference for physics teachers in developing teaching materials, diagnostic evaluations, and learning models that focus on conceptual construction, thereby minimizing misconceptions and improving the quality of understanding of direct current electricity concepts.

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