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Research Article

DIAGNOSING STUDENTS' MISCONCEPTIONS OF DIRECT CURRENT ELECTRICAL CIRCUITS USING A FIVE-TIER ISOMORPHIC INSTRUMENT

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Abstract
This study aims to diagnose students' conceptions and identify their sources related to direct current electrical circuits using a five-tier isomorphic diagnostic instrument. A quantitative method with a research and development design was used involving 108 grade XII students from State Senior High School 1 Jambi City. Data was collected through an isomorphic test of 9 questions, interviews, and documentation. Validity and reliability analysis using SPSS showed that the instrument was reliable (Cronbach's Alpha = 0.911). The implementation of this research instrument showed that the average percentage of students' correct answers (at Tier 1-4) was only 19.9%, indicating a low understanding of the concept. Then, this study also identified students' misconceptions, which included eight main types of misconceptions with an average overall percentage (at Tier 1-4) of 13.6%, which was also categorized as low. Personal thinking was identified as the primary source of misconceptions, providing important insights for designing physics learning interventions. This study's novelty lies in applying a five-tier diagnostic instrument to identify misconceptions and their sources, finding that students' thinking was the primary source. The results of this study provide important implications for physics education, including targeted intervention strategies and increased conceptual clarity, which ultimately support the teaching and learning of basic physics concepts.

Keywords: Diagnostic Test, Direct Current Electrical Circuits, Five-Tier Instrument, Isomorphic, Misconception, Physics Education.

INTRODUCTION

A strong conceptual understanding is essential for students to succeed in all academic disciplines. Student misconceptions are correlated with poor academic performance and high dropout rates (Van Hoof et al., 2021; Liu & Fang, 2023; Hyskaj et al., 2024; Risnawati et al., 2024). A strong understanding of physics is an important foundation for a nation's scientific and technological development. Physics is a science that studies knowledge systematically through careful observation and measurement (Maknun, 2020; Soeharto & Csapó, 2021; Silaban & Jumadi, 2022). Physics learning, which requires understanding hierarchical concepts to explain natural phenomena, is often considered challenging by students (Kokkonen & Schalk, 2021; Maison, Kurniawan, Wirayuda et al., 2022; Castro, 2025; Ummah & Yohamintin, 2025). In the context of teaching, students are expected to understand the concepts of the material in depth, following the demands of the applicable curriculum (Apriyanti et al., 2020; Woitkowski, 2020; Huda, Girei, & Keizi, 2023; Maymunah, Ramorola, & Shobowale, 2023). Understanding physics concepts is crucial because it helps students connect knowledge, facilitates learning, and strengthens connections between concepts (Cai et al., 2020; Banda & Nzabahimana, 2021; Nabila Junita & Dev Prasad, 2024). However, many students have difficulty understanding complex physics concepts (Jeong & So, 2020; Rizki & Setyarsih, 2022; Fitriana & Waswa, 2024; Saputra, A., Musonda, A., & Nikolantonakis, 2024). Therefore, identifying misconceptions is important in designing effective learning strategies to improve student understanding.

Misconceptions in physics are a common challenge faced by students. Students' misunderstandings of several scientific concepts, including physics, may result from misunderstanding fundamental issues (Stylos et al., 2021; Assem et al., 2023; Maudia, N., Awodeyi & Mohammed, 2024). Misconceptions are incorrect or mistaken understandings of physics concepts, usually based on everyday experiences or observations (Neidorf et al., 2019; Darmaji et al., 2022; Kulgemeyer & Wittwer, 2023). The impact of these misconceptions is very significant because they can hinder students' ability to understand more complex materials in the future and can even persist into higher education (Maison et al., 2021; Maison, Kurniawan, Yolviansyah, et al., 2022; Herliana et al., 2024). Therefore, learning must focus on eliminating misconceptions, which means that teachers must first diagnose before learning (Ilyas & Saeed, 2018; Pieschl et al., 2021; Martawijaya et al., 2023; Arsyam, Kariuki & Odango, 2024). A practical approach to addressing misconceptions must include the process of diagnosis, causes, and improvement (Gleason et al., 2021; Resbiantoro & Setiani, 2022; Miharja, Bulayi & Triet, 2024). One technique that can help diagnose students' misconceptions is using isomorphic test instruments (Ansmann & Seyfried, 2022; Sutrisno et al., 2023; Feudel & Unger, 2024). Isomorphic tests can describe students' understanding of various modes of representation and measure students' skills in transferring knowledge from one context to another (Sumarak Ningsari et al., 2021; Maison et al., 2023; Muhasriady, & Tiwari, 2024; Lamuda, Ashmawi, & Sangadji, 2024). Several studies have shown that isomorphic tests can identify students with strong, weak, or misconception understanding of concepts (Fitriani et al., 2023; Darmatiara et al., 2024; Mansyur et al., 2024; Wu et al., 2024). In addition, diagnostic tests are also an important tool in identifying student misconceptions. These tests cover a variety of formats, ranging from regular multiple-choice tests to multi-tiered diagnostic tests such as four-tier and five-tier tests (Gurel et al., 2015; Kurniawati & Ermawati, 2020).

The five-tier diagnostic test measures understanding of physics concepts and provides in-depth insight into possible misconceptions. This test includes five tiers: answers to questions, confidence levels in answers, reasons for answers, confidence levels in reasons, and student sources of information (Bayuni et al., 2018; Fatonah et al., 2022; Jumaera, Blessing, & Rukondo, 2024). This test instrument allows teachers to explore students' understanding more deeply, providing a more accurate diagnosis of misconceptions. Previous studies on diagnosing student misconceptions have been widely conducted, such as research by Trisnawati et al. (2020), which analyzed misconceptions in direct current electrical circuit material in Vocational High School students in Kendari City using four-tier diagnostics. Then, the research conducted by Inggit et al. (2021) focused on identifying misconceptions and their causes using the five-tier fluid static test (5TFST) instrument in grade XI students. In addition, research by Alatas et al. (2021) which focused on identifying student misconceptions using isomorphic instruments in Newton's law material. However, there are still gaps in previous studies; namely, the analysis of students' conceptual knowledge sources has not been identified, and a study conducted by Fitriani et al. (2023) focused on diagnosing students' conceptions of wave propagation material using a five-tier isomorphic instrument. This study can describe the misconceptions experienced by students and the causes of misconceptions that occur in students. So, to fill the gap in previous studies, this study was conducted to diagnose students' conceptions and their causes in direct current electrical circuits using a five-tier isomorphic instrument.

Based on the results of interviews conducted by researchers, common misconceptions students face include the belief that electric current 'runs out' after passing through a resistor and misunderstandings regarding voltage distribution in a circuit. Based on information from sources, it is known that in physics learning, several students still experience misconceptions about several materials, one of which is direct current electricity. This can hinder the achievement of physics learning outcomes, such as students' ability to apply electrical concepts. The causes of this misconception include students' initial understanding that is not quite right and limited teaching materials. Generally, teachers identify these misconceptions roughly through discussions, observations, and exam results without detailed data.

In line with the results of pre-research interviews, according to Purwaningtias and Putra (2020), the causes of these misconceptions come from internal and external factors. Internal factors include students not paying attention and not taking notes on the material presented by the teacher, students not studying before the test takes place, students being less careful in answering test questions, and students only memorizing material while studying without understanding the basic concepts of the material (Maison, Hidayat, et al., 2022). External factors include examples of questions given by teachers that are not varied enough, teachers are too quick in explaining the material, and books used by students are incomplete. There are no practical activities that support learning (Rovai & Pfingsthorn, 2022; Stadermann & Goedhart, 2021; Sunandar, Alvarez, & Cardozo, 2024; Yulita, Sayco, & Neto, 2024). Then, according to Inggit et al. (2021), students' thinking is the source of the most common misconceptions.

Previous research focused on developing and testing a diagnostic instrument in the form of a four-tier test to diagnose students' conceptual understanding of Series Electrical Circuit. While this instrument proved to be valid and reliable in identifying students' understanding levels such as understanding, partial understanding, misconceptions, and lack of understanding the study was limited to the scope of material covering only one type of electrical circuit (Hesti, 2022). In contrast, the current research expands its scope to include Direct Current Electrical Circuits, addressing more fundamental and comprehensive concepts in physics. Moreover, the current research develops a diagnostic instrument based on a five-tier isomorphic diagnostic instrument, which not only diagnoses students' conceptual understanding but also identifies the sources of their misconceptions, such as personal thinking patterns. This represents a significant advancement compared to the previous research, which did not explore the sources of misconceptions.

This research is urgently needed because misconceptions in physics, particularly in the material of direct current electrical circuits, often hinder students' understanding of more complex concepts in the future. Misconceptions such as the belief that electric current "runs out" after passing through a resistor or misunderstandings regarding voltage distribution highlight the need for a more in-depth diagnostic instrument. Teachers have generally identified these misconceptions roughly through discussions or exam results without structured and detailed data, creating a gap in understanding and hindering effective learning. This research aims to develop and implement a five-tier isomorphic diagnostic test instrument that not only maps students' understanding more accurately but also identifies the sources of misconceptions that are often overlooked. With this instrument, teachers will be able to diagnose students' misconceptions more effectively and design more targeted and efficient learning interventions. This research aims to provide a clearer map of students' understanding, which will support the planning of more effective lessons and ultimately improve students' grasp of fundamental physics concepts.

This research is important because misconceptions in physics, especially in the material of direct current electrical circuits, often become obstacles for students in understanding more complex concepts in the future. Teachers usually only identify these misconceptions roughly through discussions or exam results without detailed and structured data. Misconceptions such as the belief that electric current "runs out" after passing through a resistor or misunderstanding of voltage distribution indicate the need for a more in-depth diagnostic instrument. By developing a five-tier isomorphic-based diagnostic instrument, this study can provide a more accurate mapping of students' conceptions, including identifying the causes of often overlooked misconceptions. The results are expected to help teachers design more effective learning and support students in building a stronger understanding of fundamental physics concepts. Based on the above explanation, the researcher aims to diagnose students' conceptions and causes in direct current electrical circuits using a five-tier isomorphic instrument.

RESEARCH METHOD

This study uses a quantitative research design that relies on objective measurement results and mathematical or statistical analysis of data samples. The instruments used were first developed before being implemented. The subjects used as the population were Senior High School 1, Jambi City students. The researcher used a purposive sampling technique to determine the research sample. Purposive sampling is the deliberate selection of samples based on their ability to explain specific themes, concepts, or phenomena (Lenaini, 2021; Robinson, 2023). The sample in this study was 108 students from class XII of Senior High School 1, Jambi City, from classes XII.F5, XII.F6, and XII.F7.

The research sample was selected based on the criteria of students who took physics lessons and studied direct current electricity material.

This study began by identifying the problem through literature studies and preliminary studies related to students' common misconceptions about direct current electrical circuits. It then continued by adapting instruments to diagnose students' conceptions about direct current electrical circuits. The next stage is data collection and quantitative data analysis, as well as interpretation and drawing conclusions.

The data collection technique used in this study was a misconception test, interviews, and documentation. The test used was a five-tier isomorphic instrument of direct current electricity consisting of 9 items. The interviews were conducted with several students, especially those with low conceptions (Busetto et al., 2020; Monteiro et al., 2021). The five-tier isomorphic instrument in this study was a conceptual question related to direct current electric circuits. The guidelines or instructions are: at the first tier, choose the answer to each question; at the second tier, determine your level of confidence in the answer; at the third tier, choose the reason for the answer to the question; at the fourth tier, determine your level of confidence in the reason; and at the fifth tier, choose the source of information (knowledge) that you use in answering. Table 1 below presents the question grid on the isomorphic instrument.

Table 1. Diagnostic test item grid

Measured Aspects/Concepts	Number of Items	Item Number
Essential characteristics of parallel circuits	3	1, 2, 3
Distribution of electric current	2	4, 5
Characteristics of electrical circuits and fundamental laws of electricity (Ohm's Law, Kirchoff's Law, and the concept of electrical power).	4	6, 7, 8, 9

Table 1 presents the diagnostic question grid on a five-tier isomorphic instrument designed to measure students' understanding of direct current electrical circuits. The questions cover three main aspects: the relationship between current and voltage in parallel circuits (4 items), the brightness of a lamp in a parallel circuit (3 items), and changes in current and voltage due to a switch (2 items). Each question assesses students' conceptual understanding in depth by involving answers, beliefs, reasons, beliefs about reasons, and sources of information used. This instrument aims to detect students' misconceptions by presenting structured conceptual questions.

An instrument or measuring tool can be good if it meets the validity and reliability values (Nurhayati et al., 2024). Instruments that are not valid and reliable can produce inaccurate and biased conclusions related to the conditions of the subjects being measured. The instrument that researchers are currently using is valid and reliable qualitatively or in terms of the validity of the content of this research instrument is valid and reliable. So, in this study, the construct validity will be measured. The classification of instrument validity can be seen in the following table:

Table 2. Instrument Validity Classification

r value	Interpretation of Validity
$0,80 < r_{xy} \leq 1,00$	Very high
$0,60 < r_{xy} \leq 0,80$	High
$0,40 < r_{xy} \leq 0,60$	Enough
$0,20 < r_{xy} \leq 0,40$	Low
$0,00 < r_{xy} \leq 0,20$	Very low
$r_{xy} \leq 0,00$	Invalid

Then, a reliability test is also carried out, which shows the level of firmness (consistency) of a test. A test is said to be reliable if the test results show a determination. The analysis used to test reliability in this study is using Cronbach Alpha, which is found in SPSS software. The following table presents the interpretation of reliability values.

Table 3. Interpretation of reliability values

Reliability value	Interpretation
$0{,}80 < r_{11} \leq 1{,}00$	Very high reliability
$0{,}60 < r_{11} \leq 0{,}80$	High reliability
$0{,}40 < r_{11} \leq 0{,}60$	Medium reliability
$0{,}20 < r_{11} \leq 0{,}40$	Low reliability
$r_{11} \leq 0{,}20$	Very low reliability

The categories of conception based on measurements using a file-tier format instrument are as follows Table 4.

Table 4. Five-tier misconception decision categories

No.	Decision	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5
1.	SC (Scientific Conception)	Correct	Sure	Correct	Sure	Books Internet Teacher's explanation Observation results Personal thoughts Friends Others
2	LK (Lack of Knowledge)	Correct Correct Correct Correct Correct Correct Wrong Wrong Wrong Wrong Wrong Wrong Wrong	Sure Not sure Not sure Sure Not sure Not sure Sure Not sure Not sure Sure Sure Not sure Not sure	Correct Correct Correct Wrong Wrong Wrong Correct Correct Correct Correct Wrong Wrong Wrong	Not sure Sure Not sure Not sure Sure Not sure Not sure Sure Not sure Not sure Not sure Sure Not sure	Books Internet Teacher's explanation Observation results Personal thoughts Friends Others
3	MSC (Misconception)	Wrong	Sure	Wrong	Sure	Books Internet Teacher's explanation Observation results Personal thoughts Friends Others
4	FP (False Positive)	Correct	Sure	Wrong	Sure	Books Internet Teacher's explanation Observation results Personal thoughts Friends Others
5	FN (False Negative)	Wrong	Sure	Correct	Sure	Books Internet Teacher's explanation Observation results Personal thoughts Friends Others

Data analysis is the construct validity through factor analysis and Cronbach's alpha reliability. The analysis in this study uses IBM SPSS Statistic 23 software to conduct CFA tests (involving Scree Plot and Rotated Component Matrix) and Cronbach's alpha reliability tests. Scree plots and Rotated Component Matrix values are displayed in analyzing construct validity. In the Rotate Component Matrix section, the construct validity value of an instrument is obtained. Data analysis techniques for student test results using isomorphic instruments of direct current electrical circuits in a five-tier format are processed by processing raw data, then by finding the correct score for tier 1, tier 1 and 3, and then tier 1-4. For tier 1, if the answer is correct, score 1; for tiers 1 and 3, if the answer and reason are correct, score 1; and for tiers 1-4, if all are correct, score 1. With tier 5, the cause of student misconceptions can be identified (the source of students experiencing misconceptions). To obtain the total correct score for each item in percent, the following equation can be used:

$$\boldsymbol{X = \frac{\sum SB}{\sum SISWA} \times 100} \quad \textbf{... (1)}$$

Caption:
X = percentage;
SB = Correct score;
∑ = Number

RESULTS AND DISCUSSION

The validation results in this study for construct validity used a factor analysis, namely confirmatory factor analysis using SPSS. The results of the instrument validation by construct are presented in the following Table 5.

Table 5. Validity of the construct of isomorphic instruments for direct current electric circuits

Rotated Component Matrix[a]			
	Component		
	1	2	3
ITEM_9	.919		
ITEM_8	.917		
ITEM_7	.716		
ITEM_6	.671		
ITEM_1		.891	
ITEM_2		.871	
ITEM_3		.849	
ITEM_5			.912
ITEM_4			.885

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 4 iterations.

Table 5 shows that the loading value of each item of the isomorphic instrument of the five-tier format DC electric circuit correlates with the indicator and its construct. The results of the Rotated Component Matrix analysis in Table 5 show the validity of the instrument construct through the Principal Component Analysis (PCA) test with Varimax rotation. Based on the analysis results, Component 1 consists of ITEM 9, ITEM 8, ITEM 7, and ITEM 6 with high factor loading values (above 0.6), indicating that these four items significantly contribute to the component. Component 2 consists of ITEM 1, ITEM 2, and ITEM 3, which also have high factor loading values (above 0.8), indicating a strong relationship between these items and the dimensions they represent. Meanwhile, Component 3 consists of ITEM 5 and ITEM 4 with factor loading values of 0.912 and 0.885, respectively, indicating a decisive contribution to this component.

Overall, the high factor loading values on each component indicate that each item has good construct validity when measuring the intended dimensions. Varimax rotation helps maximize the interpretability of the results by distributing the factor loading values clearly on each component. The rotation process also achieved convergence in 4 iterations, indicating the stability of the rotation solution and the optimal factor structure pattern. Thus, this instrument can be considered valid for measuring isomorphic constructs in direct current electrical circuit material because the items are logically grouped in each relevant component. The results of the reliability test of the isomorphic direct current electrical circuit instrument in a five-tier format using Cronbach Alpha found in the SPSS software are presented in the following Table 6.

Tabel 6. Reabilitas instrument isomorfik rangkaian listrik arus searah berformat five-tier

Reliability Statistics	
Cronbach's Alpha	N of Items
.911	9

Based on the results of the reliability test in Table 6 above, it is known that the Cronbach's Alpha value of the instrument consisting of 9 items is 0.911> 0.60, meaning that the nine items or all question items on the isomorphic instrument of the direct current electrical circuit in the five-tier format are reliable or consistent, which is categorized as very high reliability. The results of the implementation of the isomorphic instrument of direct current electrical circuits in the five-tier format are in the following Table 7.

Table 7. Percentage of correct answers based on the number of tiers

Item	Only First Tiers (%)	First & Third Tiers (%)	All Four Tiers (%)
Item 1	80	60.2	51
Item 2	78	74.1	64
Item 3	63	50	44
Item 4	31	3.7	1.9
Item 5	17	12.9	7.4
Item 6	20	1	0.9
Item 7	44	2.8	1.9
Item 8	39	5.6	2.8
Item 9	33	9.3	5.6
Mean	45	24	19.9

The data in Table 7 reveals the variation in the average percentage of correct answers State Senior High School 1 Jambi City students, which is reviewed based on its tier. The average percentage of correct answers at the first tier reached 45%, while the average percentage at tiers 1&3 reached 24%. Overall, the average percentage of correct scores for electrical circuits, assessed from tiers one to four (with a four-tier instrument), was 19.9%. This result shows that the student's understanding of the concept can be categorized as low because the percentage of correct scores obtained was below 30%. If the data in Table 7 is represented as a graph, which illustrates the percentage of students' correct answers at tiers one, two, and four, the results will be as seen in Figure 1.

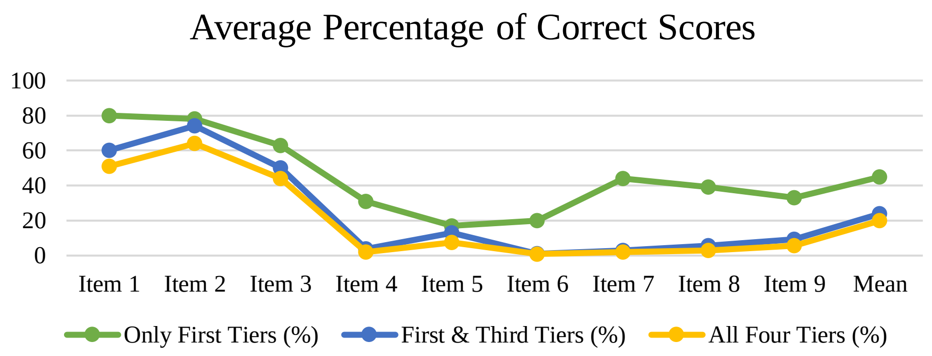


Figure 1. Average percentage of correct scores for grade 12 students in phase F at State Senior High School 1 Jambi City

The percentage of student conceptions in terms of False Negative, False Positive, Misconception, Lack of Knowledge, and Scientific Conception is presented in the following table 8.

Table 8. Percentage of student conceptions reviewed from False Negative, False Positive, Misconception, Lack of Knowledge, and Scientific Conception

Conception categories	Percentage (%)									Mean (%)
	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	
False Negative	4.6	2.8	19	5.6	2.8	0.9	7.4	5.6	1.9	5.66
False Positive	18	2.8	7.4	2.8	3.7	4.6	17	0.9	12	7.61
Misconception	7.4	2.8	3.7	0.9	7.4	0	2.8	0	21	5.14
Lack of Knowledge	19	45	22	27	22	46	26	51	20	31.1
Scientific Conception	51	46	47	64	64	48	47	43	44	50.5

Of the 108 students who worked on the DC electrical circuit isomorphic test in five tier format, 31.1% or 34 students were included in the lack of knowledge (LK) category on the material being tested. Meanwhile, for students who understood the concept, there were 50.5% or around 55 students. 5.14% or 5 students were included in the misconception category, 7.61% or 8 students were included in the false positive category and 5.66% or 6 other students were included in the false negative category. According Kaltakci-Gurel et al. (2017), suggest using false positive and false negative probability estimates to evaluate the validity of test content. To establish content validity, this proportion is recommended to be below 10%. Therefore, using the MS-Excel program this proportion is estimated. Table 5 provides this proportion for each item and the average. The average proportion of false positives was estimated at 3.5% and false negatives at 3.3%, both below the suggested 10%. Based on the results of data processing on the diagnostic tests that have been carried out, the misconception profile presented in Figure 2 was obtained.

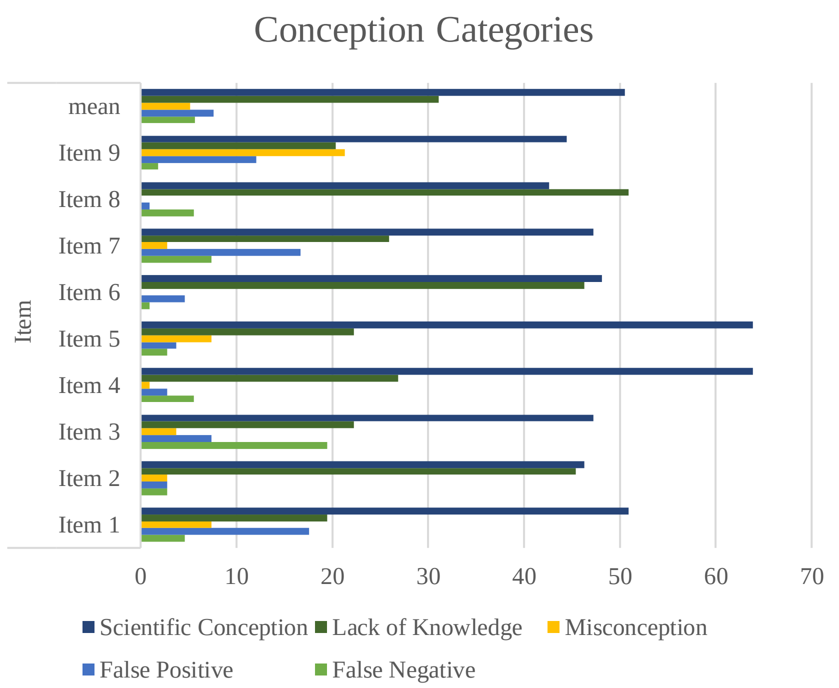


Figure 2. Percentage of student conceptions reviewed from False Negative, False Positive, Misconception, Lack of Knowledge, and Scientific Conception

Based on Figure 2, it can be seen that the biggest misconception occurs in test item number nine with a percentage of 21% with a total of 23 students related to the concept of Characteristics of electrical circuits and fundamental laws of electricity (Ohm's Law, Kirchoff's law, and the concept of electrical power). The lowest misconception occurs in test item number eight; namely, students do not experience misconceptions but are dominant in the category lack of knowledge (LK) related to the concept of Characteristics of electrical circuits and fundamental laws of electricity (Ohm's Law, Kirchoff's law, and the concept of electrical power) with a percentage of 51% and the number of students is around 55 students. According to Caleon & Subramaniam (2010), misconceptions can be significant if the number is more than 10% of the sample. Therefore, in this study, misconceptions that meet these criteria were found in question number 9. The source of information on students' knowledge related to students' conceptions of direct current electrical circuits in answering questions on isomorphic instruments of direct current electrical circuits is presented in the following diagram:

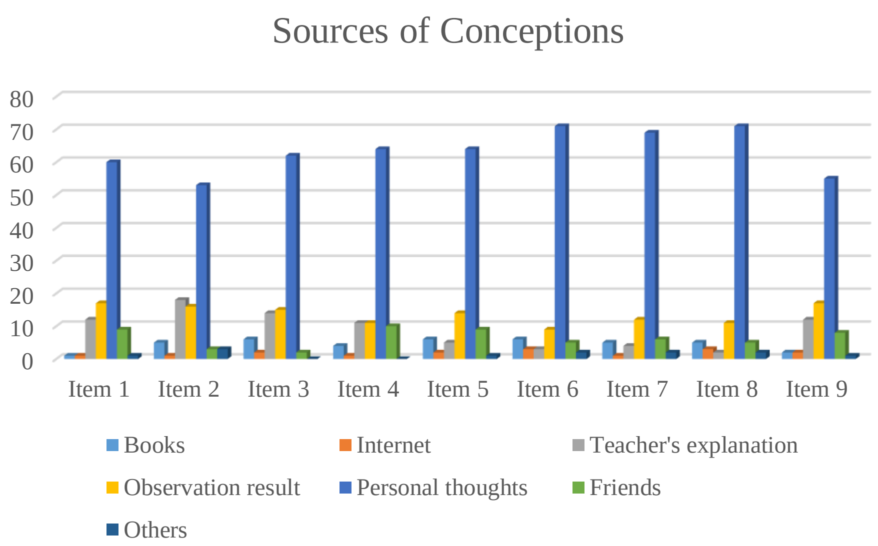


Figure 3. Sources of Student Conceptions

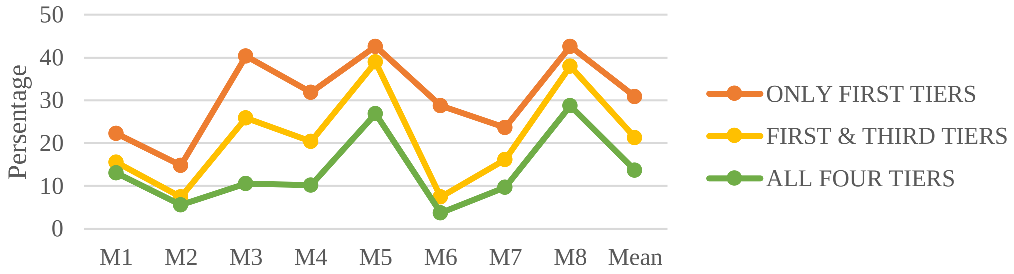
Figure 3 is a horizontal bar chart showing sources of conception based on various categories. These categories include Books, the Internet, Teacher Explanations, Observation Results, Personal Thoughts, Friends, and Others. Each category is represented by several bars with different colors, which depict the values for various "Items" (Item 1 to Item 9). Based on the graph, Personal Thoughts are the most dominant source of conception, with the highest value compared to other categories. Sources such as Teacher Explanations and Observation Results also provide significant contributions, although lower than Personal Thoughts. On the other hand, categories such as books, the Internet, friends, and others make a minor contribution to forming conceptions. This graph shows the respondents' tendency to rely on specific sources to form their conceptions, with personal thoughts being the leading choice.

The results of the data analysis for student misconceptions were analyzed in the same way as the results of the analysis of correct answers. However, the scoring was adjusted to the description of the misconception presented in Table 8 below. Students who answered according to the misconception answer key received a score of 1, but those who did not receive a score of 0. The assessment was adjusted to the description of the misconception (Gurel et al., 2015).

Table 9. Description of misconceptions of the topic of direct current electric circuits

Code	Misconception Description	Item Selection
M1	The closer to the voltage source, the greater the electric current.	1.1. a; 1.2. a; 1.3. a; 1.4. a 3.1. b; 3.2. a; 3.3. b; 3.4. a 9.1. c; 9.2. a; 9.3. d; 9.4. a
M2	The closer to the voltage source, the greater the electrical potential difference across the load.	2.1. a; 2.2. a; 2.3. a; 2.4. a
M3	The voltage source is considered a constant current source so that the total current remains constant. If the current in one branch decreases or is cut off, the current in the other branch will increase.	4.1. a; 4.2. a; 4.3. a; 4.4. a 8.1. a; 8.2. a; 8.3. a; 8.4. a
M4	There is an electric current in the open circuit branch	5.1. b; 5.2. a; 5.3. b; 5.4. a 5.1. c; 5.2. a; 5.3. c; 5.4. a
M5	There is no potential difference across the open branch.	6.1. a; 6.2. a; 6.3. a; 6.4. a
M6	If there is no current, then the potential difference is small	6.1. b; 6.2. a; 6.3. a; 6.4. a
M7	Potential difference depends on the magnitude of the current	7.1. a; 7.2. a; 7.3. a; 7.4. a 7.1. b; 7.2. a; 7.3. b; 7.4. a
M8	Branches of a circuit that do not have lights or loads do not carry electric current.	9.1. b; 9.2. a; 9.3. b; 9.4. a

Based on the analysis presented in Table 8 above, it was found that there were eight types of misconception descriptions in the concept of direct current electrical circuits. Code M1 means the first type of misconception, M2 means the second type of misconception, and so on. Then item 1 (a, a, a, a) in M1 means that the first type of misconception is in question number 1 with answer keys in tier 1 a, tier 2 a, tier 3 a, and tier 4 a. then, based on the analysis of the misconception description, the percentage is obtained as shown in Figure 4.



Misconception	M1	M2	M3	M4	M5	M6	M7	M8	Mean
Only First Tiers	22.2	14.8	40.3	31.9	42.6	28.7	23.6	42.6	30.8
First & Third Tiers	15.5	7.4	25.9	20.4	38.9	7.4	16.2	38	21.2
All Four Tiers	13	5.6	10.6	10.2	26.9	3.7	9.7	28.7	13.6

Figure 4. Percentage of descriptions of misconceptions about direct current electrical circuits based on the number of tiers.

Figure 4 illustrates the percentage of misconceptions about direct current electrical circuits classified by the number of tiers (Only First Tiers, First and third Tiers, and All Four Tiers) in eight categories of misconceptions (M1 to M8). This graph shows different patterns at each tier and provides in-depth insight into how using different tiers in the test affects the identification of misconceptions. Figure 4 above reveals the variation in the average percentage of misconceptions of students at State Senior High School 1 Jambi City reviewed based on their tiers. The average percentage of misconceptions at the first tier reached 30.8%. Then, the average percentage of misconceptions of students at tiers 1 and 3 reached 21.2%, and overall, the average percentage of students' misconception scores, assessed from tier 1 to tier 4 (using a four-tier instrument), was 13.6%. These results indicate that the misconceptions held by students can be categorized as low because the percentage of misconception scores obtained was less than 30%. This graph shows that the more tiers used in the measurement, the more detailed the percentage of misconceptions detected. This indicates that more comprehensive testing, such as a four-tier test, is more effective in identifying misconceptions in-depth and accurately.

Research relevant to the current study was conducted by Manunure et al. (2020) where the misconceptions identified were mostly similar, showing consistent problems in students across educational contexts. One of them is the identification of misconceptions on “the closer to the source, the greater the current”. However, in previous studies, the causes of misconceptions were not directly identified. So, the current study expands on previous research by identifying the main causes of misconceptions, complementing the focus on solutions in previous studies.

The results of this study provide a new contribution to the field of physics education by developing and using a five-tier isomorphic diagnostic instrument to analyze students' misconceptions on the concept of direct current electric circuits. The main novelty lies in the exploration of the sources of students' conceptions in detail through the fifth tier, which identifies the origins of students' understanding, including books, the internet, teachers, and personal thoughts, in addition to combining several items to explore the same concept makes the instrument more precise in analyzing students' understanding. This approach goes beyond previous studies that only focus on diagnosing misconceptions without exploring the origins of students’ knowledge. This study also shows the dominance of sources of misconceptions originating from personal thoughts, providing important insights for designing more effective educational interventions.

The results of this study have practical benefits in improving physics learning, especially in creating teaching strategies that are more responsive to students' misconceptions. By comprehensively identifying sources of misconceptions, teachers can change their teaching methods, such as using teaching aids or providing more in-depth explanations. However, this study has limitations in that it only covered one high school and only on direct current electrical circuit material, so the results must be generalized to more people. Recommendations for further research are to develop instruments, such as websites, that can make analysis more practical and faster.

CONCLUSION

This study successfully developed a five-tier isomorphic diagnostic instrument to analyze students' misconceptions about direct current electrical circuits. The instrument used showed good construct validity with high factor loading values on each component and very high reliability with a Cronbach's Alpha value of 0.911. The implementation of this instrument revealed that students' conceptual understanding was still low, with an average percentage of correct answers for all tiers of 19.9%. In addition, this study also successfully identified students' misconceptions, which included eight main types of misconceptions with an average overall percentage of 13.6%, which was categorized as low. Practically, this study improves physics learning by providing a diagnostic tool that can comprehensively identify students' misconceptions. However, this study was limited to one school, so the results cannot be generalized to a broader population. Therefore, further research is recommended to develop this instrument in a digital form based on a website so that the analysis can be carried out more practically and efficiently.

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AUTHOR CONTRIBUTIONS

Conceptualization, Elza Triani, Maison, and Nazaruddin; Software, SPSS statistic 23 software; Investigation, students, teachers, and SMA Negeri 1 Kota Jambi staff.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

REFERENCES

Alatas, F., Ilhamiah, S., & Suryadi, A. (2021). Identification of students' misconceptions using isomorphic test: the case of newton's law of motion. *Edusains*, *13*(2), 174–184. https://doi.org/10.15408/es.v13i2.23967.

Ansmann, M., & Seyfried, M. (2022). Isomorphism and organizational performance: evidence from quality management in higher education., 30(1), 135–149. https://doi.org/10.1108/QAE-07-2021-0114.

Arsyam, S. P. Y., Kariuki , M. N., & Odango, J. M. (2024). Enhancing animal physiology practicum: Exploring students' perceptions and influencing factors. *Journal of Academic Biology and Biology Education*, *1*(2), 56 - 65. https://doi.org/10.37251/jouabe.v1i2.1149

Assem, H. D., Nartey, L., Appiah, E., & Aidoo, J. K. (2023). A review of students' academic performance in physics: attitude, instructional methods, misconceptions and teachers qualification. *European Journal of Education and Pedagogy*, *4*(1), 84–92. https://doi.org/10.24018/ejedu.2023.4.1.551.

Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, *17*(2), 23108. https://doi.org/10.1103/PhysRevPhysEducRes.17.023108.

Bayuni, T. C., Sopandi, W., & Sujana, A. (2018). Identification misconception of primary school teacher education students in changes of matters using a five-tier diagnostic test. *Journal of Physics: Conference Series*, *1013*(1), 0–7. https://doi.org/10.1088/1742-6596/1013/1/012086.

Busetto, L., Wick, W. & Gumbinger, C. How to use and assess qualitative research methods. *Neurol. Res. Pract.* **2**, 14 (2020). https://doi.org/10.1186/s42466-020-00059-z.

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C. (2020). Effects of learning physics using Augmented Reality on students self efficacy. In *British Journal of Educational Technology* (Vol. 52, Issue 1, pp. 235–251).

Castro, R. (2025). The effects of chemistry virtual laboratories in academic achievement of secondary level learners: A Meta-Analysis. *Integrated Science Education Journal*, *6*(1), 24-37. https://doi.org/10.37251/isej.v6i1.1379

Darmaji, D., Astalini, A., Kurniawan, D. A., & Triani, E. (2022). The effect of science process skills of students argumentation skills. *Jurnal Inovasi Pendidikan IPA*, 8(1), 78–88. https://doi.org/10.21831/jipi.v8i1.49224.

Darmatiara, D., Pratama, W. A., Susbiyanto, S., & Chaw-Yangon , E. P. C.-Y. . (2024). Identification of students' responses towards stem-based physics learning videos on momentum and impulse materials. *EduFisika: Jurnal Pendidikan Fisika*, *9*(2), 173-181. https://doi.org/10.59052/edufisika.v9i2.24927

Fatonah, U., Maison, M., & Hidayat, M. (2022). Development of Five-Tier diagnostic test to identify misconception in rigid body equilibrium. *Berkala Ilmiah Pendidikan Fisika*, *10*(2), 199. https://doi.org/10.20527/bipf.v10i2.13077.

Feudel, F., & Unger, A. (2024). Development and implementation of Concept-Test questions in abstract algebra. *International Journal of Mathematical Education in Science and Technology*. https://doi.org/10.1080/0020739X.2023.2297002.

Fitriani, R., Maison, Asrial, Purwaningsih, S., & Asma, R. (2023). Diagnosing students' conception of wave propagation using the five-tier isomorphic instrument. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9461–9473. https://doi.org/10.29303/jppipa.v9i11.5413.

Fitriana, H., & Waswa, A. N. (2024). The influence of a realistic mathematics education approach on students' mathematical problem solving ability. *Interval: Indonesian Journal of Mathematical Education*, *2*(1), 29-35. https://doi.org/10.37251/ijome.v2i1.979

Gleason, K., Harkless, G., Stanley, J., Olson, A. P. J., & Graber, M. L. (2021). The critical need for nursing education to address the diagnostic process. *Nursing Outlook*, *69*(3), 362–369. https://doi.org/10.1016/j.outlook.2020.12.005.

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a.

Herliana, Maison, & Syaiful. (2024). Development and Implementation of a Five-Tier Diagnostic Test To Identify Student Misconceptions on Fractions: a Significant Step Towards Improving Mathematics Education. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *8*(2), 563–576. https://doi.org/10.22437/jiituj.v8i2.34159.

Hesti, R. (2022). Identifying Students' Conceptual Profile on Science Through Series Electrical Circuits Conceptual Survey with Four-Tier Diagnostic Test. *Proceedings of the International Conference on Madrasah Reform 2021* (ICMR 2021), 633(Icmr 2021), 125–130. https://doi.org/10.2991/assehr.k.220104.019.

Huda, I., Girei, M. M., & Keizi, F. (2023). Development of a practical tool for linear momentum collisions using a microcontroller. *Journal of Educational Technology and Learning Creativity*, *1*(2), 42-49. https://doi.org/10.37251/jetlc.v1i2.788

Hyskaj, A., Ramadhanti, A., Farhan , H., Allaham, A., & Ismail, M. A. (2024). Analysis of the role of the flo application as a digital educational media for adolescent reproductive health in the technology era. *Journal of Educational Technology and Learning Creativity*, *2*(1), 71-82. https://doi.org/10.37251/jetlc.v2i1.1414

Ilyas, A., & Saeed, M. (2018). Exploring Teachers' Understanding about Misconceptions of Secondary Grade Chemistry Students. *International Journal for Cross-Disciplinary Subjects in Education*, *9*(1), 3323–3328. https://doi.org/10.20533/ijcdse.2042.6364.2018.0444.

Inggit, S. M., Liliawati, W., & Suryana, I. (2021). Identifikasi Miskonsepsi dan Penyebabnya Menggunakan Instrumen Five-Tier Fluid Static Test (5TFST) pada Peserta Didik Kelas XI Sekolah Menengah Atas [Identification of Misconceptions and Their Causes Using the Five-Tier Fluid Static Test (5TFST) Instrument in Grade XI High School Students]. *Journal of Teaching and Learning Physics*, *6*(1), 49–68. https://doi.org/10.15575/jotalp.v6i1.11016.

Jeong, H. C., & So, W. Y. (2020). Difficulties of online physical education classes in middle and high school and an efficient operation plan to address them. *International Journal of Environmental Research and Public Health*, *17*(19), 1–13. https://doi.org/10.3390/ijerph17197279.

Jumaera, S., Blessing, O. T., & Rukondo, N. (2024). Optimizing student activities and learning outcomes through problem solving models in stoichiometry material. *Journal of Chemical Learning Innovation*, *1*(2), 39-44. https://doi.org/10.37251/jocli.v1i2.1147.

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics. *Research in Science and Technological Education*, *35*(2), 238–260. https://doi.org/10.1080/02635143.2017.1310094.

Kokkonen, T., & Schalk, L. (2021). One Instructional Sequence Fits all? A Conceptual Analysis of the Applicability of Concreteness Fading in Mathematics, Physics, Chemistry, and Biology Education. *Educational Psychology Review*, *33*(3), 797–821. https://doi.org/10.1007/s10648-020-09581-7.

Kulgemeyer, C., & Wittwer, J. (2023). Misconceptions in Physics Explainer Videos and the Illusion of Understanding: an Experimental Study. *International Journal of Science and Mathematics Education*, *21*(2), 417–437. https://doi.org/10.1007/s10763-022-10265-7.

Kurniawati, D. M., & Ermawati, F. U. (2020). Analysis Students' Conception Using Four-Tier Diagnostic Test for Dynamic Fluid Concepts. *Journal of Physics: Conference Series*, *1491*(1), 0–7. https://doi.org/10.1088/1742-6596/1491/1/012012.

Lamuda, V., Ashmawi, U., & Sangadji, M. (2024). Tourism area development strategy banda naira islands. *Multidisciplinary Journal of Tourism, Hospitality, Sport and Physical Education*, *1*(2), 37-49. https://doi.org/10.37251/jthpe.v1i2.1183.

Lenaini, I. (2021). Teknik Pengambilan Sampel Purposive Dan Snowball Sampling. *HISTORIS: Jurnal Kajian, Penelitian & Pengembangan Pendidikan Sejarah*, *6*(1), 33–39. http://journal.ummat.ac.id/index.php/historis

Liu, G., & Fang, N. (2023). The effects of enhanced hands-on experimentation on correcting student misconceptions about work and energy in engineering mechanics. *Research in Science and Technological Education*, *41*(2), 462–481. https://doi.org/10.1080/02635143.2021.1909555.

Maison, M., Kurniawan, D. A., & Widowati, R. S. (2021). The quality of four-tier diagnostic test misconception instrument for parabolic motion. *Jurnal Pendidikan Dan Pengajaran*, *54*(2), 359. https://doi.org/10.23887/jpp.v54i2.35261.

Maison, Hidayat, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). How critical thinking skills influence misconception in electric field. *International Journal of Educational Methodology*, *8*(2), 377–390. https://doi.org/https://doi.org/10.12973/ijem.8.2.377.

Maison, M., Hidayati, H., Kurniawan, D. A., & Fitriani, R. (2023). Using an isomorphic instrument: what do physics education students think about buoyance?. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9937–9944. https://doi.org/10.29303/jppipa.v9i11.5341.

Maison, M., Kurniawan, D. A., Wirayuda, R. P., & Chen, D. (2022). Process Skills-Based E-Module: Impact On Analytical Thinking Skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *8*(1), 23–34. https://doi.org/10.21009/1.08103.

Maison, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). Students' Misconceptions: Viewed from students' perceptions on magnetic field learning. *JPI (Jurnal Pendidikan Indonesia)*, *11*(3), 492–500. https://doi.org/10.23887/jpiundiksha.v11i3.43752.

Maknun, J. (2020). Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students. *International Education Studies*, *13*(6), 117. https://doi.org/10.5539/ies.v13n6p117.

Manunure, K., Delserieys, A., & Castéra, J. (2020). The effects of combining simulations and laboratory experiments on Zimbabwean students' conceptual understanding of electric circuits. *Research in Science and Technological Education*, *38*(3), 289–307. https://doi.org/10.1080/02635143.2019.1629407.

Mansyur, H. ., Oktavia, S. W., Andriyanto, A., & Susbiyanto, S. (2024). Identification of discovery learning methods to increase student learning motivation. *EduFisika: Jurnal Pendidikan Fisika*, *9*(2), 165-172. https://doi.org/10.59052/edufisika.v9i2.32656

Martawijaya, M. A., Rahmadhanningsih, S., Swandi, A., Hasyim, M., & Sujiono, E. H. (2023). The effect of applying the ethno-stem-project-based learning model on students' higher-order thinking skill and misconception of physics topics related to lake tempe, Indonesia. *Jurnal Pendidikan IPA Indonesia*, *12*(1), 1–13. https://doi.org/10.15294/jpii.v12i1.38703.

Maudia, N., Awodeyi, A. F., & Mohammed, A. S. (2024). Enhancing pedagogical content knowledge in mathematics teachers through collaborative professional development. *Interval: Indonesian Journal of Mathematical Education*, *2*(1), 36-49. https://doi.org/10.37251/ijome.v2i1.1342

Maymunah, A., Ramorola, M., & Shobowale, I. O. (2023). Development of an Inquiry-Based science module on plant parts and their functions in elementary schools. *Journal of Educational Technology and Learning Creativity*, *1*(2), 50-58. https://doi.org/10.37251/jetlc.v1i2.789

Miharja, M. A., Bulayi, M., & Triet, L. V. M. (2024). Realistic mathematics education: Unlocking problem-solving potential in students. *Interval: Indonesian Journal of Mathematical Education*, *2*(1), 50-59. https://doi.org/10.37251/ijome.v2i1.1344

Monteiro, V., Mata, L., & Santos, N. N. (2021). Assessment Conceptions and Practices: Perspectives of Primary School Teachers and Students. *Frontiers in Education*, 6(April), 1–15. https://doi.org/10.3389/feduc.2021.631185.

Muhasriady, M., & Tiwari, S. S. (2024). Examining the Influence of maternal education, nutritional knowledge, and toddler food intake on nutritional status. *Journal of Health Innovation and Environmental Education*, *1*(2), 38-46. https://doi.org/10.37251/jhiee.v1i2.1211

Nabila Junita, D., & Dev Prasad, R. (2024). The effect of using english animation videos on students' speaking ability. *Journal of Language, Literature, and Educational Research*, *1*(2), 39-44. https://doi.org/10.37251/jolle.v1i2.1063

Neidorf, T., Arora, A., Erberber, E., Tsokodayi, Y., & Mai, T. (2019). Student Misconceptions and Errors in Physics and Mathematics. In *IEA Research for Education* (Vol. 9). Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-30188-0.

Nurhayati, R., Aw, S., Dwiningrum, S. I. A., Hajaroh, M., & Herwin, H. (2024). Validity and reliability of child-friendly school policy evaluation instruments in primary schools: Confirmatory factor analysis. *International Journal of Educational Methodology*, *10*(1), 165-177. https://doi.org/10.12973/ijem.10.1.965.

Nurmandi, A., Muttaqin, A., Akbar, B., Fernandez, D., Arofiati, F., Fajar, M. N. D., Khalil, M., Ismail, N., & Sulistyaningsih, T. (2019). *Pedoman SPMI PTMA [PTMA SPMI Guidelines]*. Yogyakarta: Majelis Diktilitbang PP Muhammadiyah.

Pieschl, S., Budd, J., Thomm, E., & Archer, J. (2021). Effects of Raising Student Teachers' Metacognitive Awareness of Their Educational Psychological Misconceptions. *Psychology Learning and Teaching*, *20*(2), 214–235. https://doi.org/10.1177/1475725721996223.

Purwaningtias, W. S., & Putra, N. M. D. (2020). Analisis tingkat pemahaman konsep dan miskonsepsi fisika pada pokok bahasan alat-alat optik di SMA Negeri 1 Purwodadi [Analysis of the level of understanding of concepts and misconceptions of physics on the topic of optical instruments at State Senior High School 1 Purwodadi]. *UPEJ Unnes Physics Education Journal*, 9(2), 139–148. https://doi.org/10.15294/upej.v9i2.41920.

Resbiantoro, G., Setiani, R., & Dwikoranto. (2022). A Review of Misconception in Physics: The Diagnosis, Causes, and Remediation. *Journal of Turkish Science Education*, *19*(2), 403–427. https://doi.org/10.36681/tused.2022.128.

Risnawati, Ramadan, M., Baba, K., Hammad, S., & Rustaminezhad, M. A. (2024). The impact of augmented reality-based learning media on students' digital literacy skills: A study on junior high school students. *Journal of Educational Technology and Learning Creativity*, *2*(1), 63-70. https://doi.org/10.37251/jetlc.v2i1.1415

Rizki, C., & Setyarsih, W. (2022). Identifikasi Miskonsepsi Siswa dan Penyebabnya pada Materi Elastisitas Menggunakan Three–Tier Diagnostic Tes [Identification of Student Misconceptions and Their Causes in Elasticity Material Using Three-Tier Diagnostic Test]. *Inovasi Pendidikan Fisika*, *11*(3), 32–43. https://doi.org/10.26740/ipf.v11n3.p32-43.

Robinson, R. S. (2023). *Purposive Sampling BT - Encyclopedia of Quality of Life and Well-Being Research* (F. Maggino (ed.); pp. 5645–5647). Springer International Publishing. https://doi.org/10.1007/978-3-031-17299-1_2337.

Rovai, A., & Pfingsthorn, J. (2022). "Good Foreign Language Teachers Pay Attention to Heterogeneity": Conceptualizations of Differentiation and Effective Teaching Practice in Inclusive EFL Classrooms by German Pre-Service Teachers. *Languages*, 7(3). https://doi.org/10.3390/languages7030162.

Saputra, A., Musonda, A., & Nikolantonakis, K. (2024). Transformation of character assessment through ict technology: A study of the use of web-based platforms. *Interval: Indonesian Journal of Mathematical Education*, *2*(1), 60-68. https://doi.org/10.37251/ijome.v2i1.1345

Silaban, Y. F. H., & Jumadi, J. (2022). Concept understanding profile of high school students on doppler effect and sound intensity levels. *Momentum: Physics Education Journal*, *6*(1), 51–58. https://doi.org/10.21067/mpej.v6i1.5664.

Soeharto, S., & Csapó, B. (2021). Evaluating item difficulty patterns for assessing student misconceptions in science across physics, chemistry, and biology concepts. *Heliyon*, *7*(11). https://doi.org/10.1016/j.heliyon.2021.e08352.

Stadermann, H. K. E., & Goedhart, M. J. (2021). Why and how teachers use nature of science in teaching quantum physics: Research on the use of an ecological teaching intervention in upper secondary schools. Ph*ysical Review Physics Education Research*, 17(2), 20132. https://doi.org/10.1103/PhysRevPhysEducRes.17.020132.

Stylos, G., Sargioti, A., Mavridis, D., & Kotsis, K. T. (2021). Validation of the thermal concept evaluation test for Greek university students' misconceptions of thermal concepts. *International Journal of Science Education*, *43*(2), 247–273. https://doi.org/10.1080/09500693.2020.1865587.

Sutrisno, S., Maison, M., Marzal, J., & Kurniawan, W. (2023). *Rapid Artificial Diagnostic Test in Intelligent Teacher Assistant System (ITAS) to Identify Misconceptions on Kinematic*s. Atlantis Press SARL. https://doi.org/10.2991/978-2-38476-012-1_39.

Sumarak Ningsari, I., Zainuddin, A., & Setyarsih, W. (2021). Literature review of isomorphic instruments as physics learning assessment. *Jurnal Hasil Kajian, Inovasi, Dan Aplikasi Pendidikan Fisika*, *7*(1), 54–64. https://doi.org/10.31764/orbita.v7i1.4407.

Sunandar, S., Alvarez, A. S. I., & Cardozo, C. A. (2024). The influence of the use of role playing methods and interest in learning on the english speaking ability. *Tekno - Pedagogi : Jurnal Teknologi Pendidikan*, *14*(1), 16-24. https://doi.org/10.22437/teknopedagogi.v14i1.32519

Trisnawati, A., Erniwati, E., & Eso, R. (2020). Analisis Miskonsepsi terhadap Materi Rangkaian Listrik Searah (DC) Pada Siswa SMK Negeri Kota Kendari Menggunakan Four-Tier Diagnostic Test. *Jurnal Penelitian Pendidikan Fisika*, 5(4), 287. https://doi.org/10.36709/jipfi.v5i4.14097.

Ummah, W. T., & Yohamintin, Y. (2025). Integrating scientific attitude to realize pancasila learner profile in science learning. *Integrated Science Education Journal*, *6*(1), 15-23. https://doi.org/10.37251/isej.v6i1.1318.

Van Hoof, J., Engelen, A. S., & Van Dooren, W. (2021). How robust are learners' misconceptions of fraction magnitude? An intervention study comparing the use of refutation and expository text. *Educational Psychology*, *41*(5), 524–543. https://doi.org/10.1080/01443410.2021.1908521.

Yulita, Y., Sayco, S. C. C., & Neto, A. J. M. (2024). Development of wordless comic media for learning speaking class v primary school students. *Tekno - Pedagogi : Jurnal Teknologi Pendidikan*, *14*(1), 25-32. https://doi.org/10.22437/teknopedagogi.v14i1.32547

Woitkowski, D. (2020). Tracing physics content knowledge gains using content complexity levels. *International Journal of Science Education*, *42*(10), 1585–1608. https://doi.org/10.1080/09500693.2020.1772520.

Wu, M., Tian, P., Sun, D. *et al.* Evaluating Students' Conceptual Understanding of Isomers Based on a Four-Tier Diagnostic Tool in Upper Secondary Schools. *Int J of Sci and Math Educ* (2024). https://doi.org/10.1007/s10763-024-10494-y