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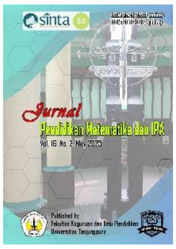

DEVELOPMENT OF A FIVE-TIER DIAGNOSTIC TEST TO IDENTIFY STUDENTS' MISCONCEPTIONS ON ELASTICITY AND HOOKE'S LAW

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Abstract
This study aims to diagnose students' conceptions and identify their sources related to elasticity and Hooke's law using a five-level multirepresentation diagnostic instrument. A quantitative method with a research and development design was used involving 33 eleventh-grade students from SMA Negeri 13 Jambi City. Data were collected through a 15-question multirepresentation test, 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 Levels 1-4) was only 19.9%, indicating low conceptual understanding. Then, this study also identified students' misconceptions, which included 14 main types of misconceptions with an overall average percentage (at Levels 1-4) of 13.6%, which is also categorized as low. Personal thinking was identified as the main source of misconceptions, providing important insights for designing physics learning interventions. The uniqueness of this study lies in the application of a five-level diagnostic instrument to identify misconceptions and their sources, by finding that students' thinking is the main 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, Elasticity, Five-Tier Test, Hooke's Law, Misconceptions*

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 [68]; [32]; [21]; [54]. A strong understanding of physics is an important foundation for a nation's scientific and technological

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development. Physics is a science that studies knowledge systematically through careful observation and measurement [38]; [60]; [59]. Physics learning, which requires understanding hierarchical concepts to explain natural phenomena, is often considered challenging by students [27]; [34]; [9]; [67]. In the context of teaching, students are expected to understand the concepts of the material in depth, following the demands of the applicable curriculum [70]; [20]; [43]. Understanding physics concepts is crucial because it helps students connect knowledge, facilitates learning, and strengthens connections between concepts [8]; [5]; [47]. However, many students have difficulty understanding complex physics concepts [24]; [55]; [15]; [58]. 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 [62]; [4]; [42]. Misconceptions are incorrect or mistaken understandings of physics concepts, usually based on everyday experiences or observations [48]; [10]; [28]. 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 [33]; [34]; [18]. Therefore, learning must focus on eliminating misconceptions, which means that teachers must first diagnose before learning [22]; [51]; [41]; [3]. A practical approach to addressing misconceptions must include the process of diagnosis, causes, and improvement [16]; [53]; [44]. One technique that can help diagnose students' misconceptions is using isomorphic test instruments [2]; [63]; [13]. Isomorphic tests can describe students' understanding of various modes of representation and measure students' skills in transferring knowledge from one context to another [64]; [63]; [30]. Several studies have shown that isomorphic tests can identify students with strong, weak, or misconception understanding of concepts [14]; [11]; [40]; [71]. 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 [17]; [29].

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 [6]; [12]; [25]. 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 [66], 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 [23] focused on identifying misconceptions and their

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causes using the five-tier fluid static test (5TFST) instrument in grade XI students. In addition, research by [1] 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 [14] 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 multi-representation 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 [52], 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 [34] 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 [57]; [61]; [65]; [69]. Then, according to [23], students' thinking is the source of the most common misconceptions.

Previous research primarily focused on developing diagnostic instruments to assess students' conceptual understanding in various physics topics such as Newton's laws, energy, and motion. However, studies specifically targeting Elasticity and Hooke's Law remain limited in scope and depth. For instance, most existing instruments employ traditional multiple-choice formats or three-tier tests that only measure students' final answers and levels of confidence without identifying the underlying causes of their misconceptions (Putra, 2021). In contrast, the present research expands on these approaches by developing a five-tier multi-representation diagnostic instrument that not only measures students' understanding of Elasticity and Hooke's Law but also investigates the

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sources of misconceptions, such as intuitive reasoning errors and misinterpretation of representations (graphs, formulas, and real phenomena). This represents a significant improvement over previous works that merely focused on identifying misconceptions without analyzing their cognitive origins.

This research is urgently needed because misconceptions related to Elasticity and Hooke’s Law are common and often hinder students’ ability to understand advanced physics concepts such as stress–strain relationships, material properties, and energy in deformation. Common misconceptions include the belief that the spring constant depends on the amount of load applied, or that the extension of a spring increases nonlinearly with force even within the elastic limit. These misunderstandings indicate the need for a more detailed and structured diagnostic approach. Teachers typically identify such misconceptions only through conventional tests or classroom observations, which do not provide systematic data on students’ reasoning processes.

Therefore, this study aims to develop and implement a five-tier isomorphic diagnostic test on Elasticity and Hooke’s Law that can provide an accurate mapping of students’ conceptual understanding levels ranging from understanding, partial understanding, misconception, to lack of understanding while also identifying the specific sources of errors in students’ reasoning. Through this instrument, teachers will gain deeper insights into students’ thought processes and be able to design more targeted learning interventions. This research is expected to contribute significantly to physics education by providing a comprehensive diagnostic tool that enhances the identification of students’ conceptual structures in Elasticity and Hooke’s Law. Ultimately, the findings will help improve instructional strategies, strengthen students’ conceptual foundations, and minimize persistent misconceptions in mechanics-related topics.

METHOD

This study employed a quantitative research design that relies on objective measurements and mathematical or statistical analysis of sample data. The instruments used were developed prior to implementation. The population consisted of students at SMA Negeri 13, Jambi City. 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 a particular theme, concept, or phenomenon [31]; [56]. The sample in this study was 33 eleventh-grade students of SMA Negeri 1, Jambi City, from class XI Science 6.

The sample was selected based on the criteria of students taking physics lessons and having studied elasticity and Hooke's law.

This study began by identifying the problem through a literature review and preliminary study related to common student misconceptions about elasticity and Hooke's law. This was followed by adapting an instrument to diagnose students' understanding of elasticity and Hooke's law. The next stage was data collection and

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quantitative data analysis, as well as interpretation and drawing conclusions.

The data collection techniques used in this study included misconception tests, interviews, and documentation. The test used was a five-level multirepresentational instrument on elasticity and Hooke's law consisting of 15 items. Interviews were conducted with several students, especially those with low conceptual understanding [7]; [45]. The five-level multirepresentational instrument in this study consisted of conceptual questions related to elasticity and Hooke's law. The guidelines or instructions were: at the first level, select an answer for each question; at the second level, determine your level of confidence in that answer; at the third level, select a reason for the answer; at the fourth level, determine your level of confidence in that reason; and at the fifth level, provide an open-ended statement from the student (knowledge) that you used in your answer.

Table 1. Presents the question grid in the multirepresentational instrument

Measured Aspects/concepts	Number of items	Item Number
Spring arrangement and oscillation period	3	1,2,3
Stress and strain relationships	2	4,5
Force and spring constant in spring systems	2	6,7
Elasticity characteristics and Hooke's Law	3	8,9,10
Young's Modulus	3	11,12,13
Hooke's Law in contextual applications	2	14,15

Table 1 presents a diagnostic question grid on a five-level multi-representation instrument designed to measure students' understanding of elasticity and Hooke's Law. The questions cover six main aspects: spring structure and oscillation period (3 items), stress-strain relationship (2 items), force and spring constant in a spring system (2 items), elastic characteristics and Hooke's Law (3 items), Young's Modulus (3 items), and Hooke's Law in contextual applications (2 items). Each question assesses students' conceptual understanding in depth by examining students' answers, beliefs, reasons, beliefs about reasons, and open-ended statements. This instrument aims to detect student misconceptions by presenting structured conceptual questions.

An instrument or measuring tool can be considered good if it meets validity and reliability requirements [49]. An instrument that is not valid and reliable can produce inaccurate and biased conclusions related to the condition of the subject being measured. The instrument currently used by the researcher is qualitatively valid and reliable, or in terms of content validity, this research instrument is valid and reliable. Therefore, in this study, construct validity will be measured. The instrument validity classification can be seen in Table 2.

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

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
$r_{11} \leq 0,00$	Very Low Reliability

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Table 4. Five-tier misconception decision categories

No.	Decision	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5 (Open-ended Student Statement)
1	SC (Scientific Conception)	Correct	Sure	Correct	Sure	Open-ended explanation scientifically consistent
		Correct	Sure	Correct	Not sure	Explanation incomplete/ uncertain
		Correct	Not sure	Correct	Sure	Explanation incomplete / uncertain
		Correct	Not sure	Correct	Not sure	Explanation incomplete / uncertain
		Correct	Sure	Wrong	Not sure	Explanation inconsistent / weak reasoning
		Correct	Not sure	Wrong	Sure	Explanation inconsistent / weak reasoning
2	LK (Lack of Knowledge)	Correct	Not sure	Wrong	Not sure	Explanation inconsistent / weak reasoning
		Wrong	Sure	Correct	Not sure	Explanation incomplete / guessing
		Wrong	Not sure	Correct	Sure	Explanation incomplete / guessing
		Wrong	Not sure	Correct	Not sure	Explanation incomplete / guessing

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No.	Decision	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5 (Open-ended Student Statement)
		Wrong	Sure	Wrong	Not sure	Explanation incomplete / guessing
		Wrong	Not sure	Wrong	Sure	Explanation incomplete / guessing
		Wrong	Not sure	Wrong	Not sure	Explanation incomplete / guessing
3	MSC (Misconception)	Wrong	Sure	Wrong	Sure	Open-ended explanation reveals alternative conception / misconception
4	FP (False Positive)	Correct	Sure	Wrong	Sure	Explanation shows misconception despite correct answer
5	FN (False Negative)	Wrong	Sure	Correct	Sure	Explanation scientifically correct despite wrong answer

The data analysis conducted was construct validity through factor analysis and Cronbach's alpha reliability. The analysis in this study used IBM SPSS Statistics 23 software to conduct CFA tests (involving Scree Plot and Rotated Component Matrix) and Cronbach's alpha reliability tests. The Scree Plot and Rotated Component Matrix values are displayed in analyzing construct validity. In the Rotated Component Matrix section, the construct validity value of an instrument is obtained. The data analysis technique for student test results using the multi-representation elasticity instrument and Hooke's law in a five-level format is processed by processing the raw data, then by finding the correct value for tier 1, tiers 1 and 3, and then tiers 1-4. For tier 1, if the answer is correct, the value is 1; for tiers 1 and 3, if the answer and reason are correct, the value is 1; and for tiers 1-4, if all are correct, the value is 1. At tier 5, the causes of student misunderstandings can be identified (open statements of students who experience misunderstandings). To obtain the total correct value for each item in percent, the following equation can be used:

$$x = \frac{\sum SB}{\sum SISWA} \times 100 \ldots (1)$$

Caption:
X = percentage;
SB = Correct score;
$\sum$ = Number

RESULT 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 Table 5. Table 5 shows that the loading value of each item in the instrument correlates strongly with its respective indicator

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and construct. The results of the Rotated Component Matrix analysis demonstrate the construct validity of the instrument through the Principal Component Analysis (PCA) test with Varimax rotation.

Table 5. Validity of the construction of multirepresentation instruments for elasticity and Hooke's law

Rotated Component Matrix[a]			
	Component		
	1	2	3
ITEM1	.936		
ITEM2	.959		
ITEM3	.900		
ITEM4	.914		
ITEM5	.856		
ITEM6		.882	
ITEM7		.887	
ITEM8		.768	
ITEM9		.885	
ITEM10		.924	
ITEM11			.800
ITEM12			.852
ITEM13			.859
ITEM14			.884
ITEM15			.837

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

Based on the analysis results, Component 1 consists of ITEM1, ITEM2, ITEM3, ITEM4, and ITEM5 with high factor loading values ranging from 0.856 to 0.959, indicating that these five items significantly contribute to the first component and have a strong relationship with the dimension they represent. Component 2 consists of ITEM6, ITEM7, ITEM8, ITEM9, and ITEM10 with factor loading values ranging from 0.768 to 0.924, showing that these items make a substantial contribution to the second component and are grouped consistently within the same construct. Meanwhile, Component 3 consists of ITEM11, ITEM12, ITEM13, ITEM14, and ITEM15 with factor loading values ranging from 0.800 to 0.884, indicating a strong contribution of these items to the third component.

Overall, the high factor loading values on each component (all above 0.6) indicate that each item has good construct validity in measuring the intended dimensions. The clear grouping of items into three components without significant cross-loading further confirms that the instrument has a well-defined factor structure. Varimax rotation helps maximize the interpretability of the results by distributing factor loading values clearly across components. The rotation process also achieved

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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 the intended constructs because the items are logically and consistently grouped into each relevant component. The results of the reliability test of the instrument using Cronbach's Alpha obtained from SPSS software are presented in the following Table 6.

Table 6. Reliabilitas instrument multireprecentation elasticity and hooke's law five tier

Reliability Statistics	
Cronbach's Alpha	N of Items
.862	15

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 15 items is 0.862 > 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 multireprecentation instrument of elasticity and hooke's law in the five-tier format are in Table 7. The data in Table 7 reveals the variation in the average percentage of correct answers of students based on the number of tiers analyzed. The average percentage of correct answers at the first tier reached 73%, indicating that most students were able to answer conceptual questions correctly at the initial response level. However, the average percentage decreased to 58.3% for the first and third tiers, showing that fewer students were able to provide both correct answers and consistent reasoning. Furthermore, the average percentage of correct answers across all four closed tiers reached 47.7%, which indicates a further decrease when students' responses were evaluated comprehensively across all closed-ended tiers of the five-tier diagnostic instrument.

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

Item	**Only First Tier (%)**	**First & Third Tiers (%)**	**All Four Closed Tiers (%)**
Item 1	82	68	56
Item 2	85	72	61
Item 3	79	65	54
Item 4	76	61	50
Item 5	74	58	47
Item 6	68	53	43
Item 7	71	56	45
Item 8	66	49	39
Item 9	69	52	42

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Item	Only First Tier (%)	First & Third Tiers (%)	All Four Closed Tiers (%)
Item 10	73	57	46
Item 11	70	54	44
Item 12	72	56	46
Item 13	75	60	49
Item 14	74	59	48
Item 15	71	55	45
MEAN	73,6666667	58,3333333	47,6666667

This result shows that although students demonstrated relatively good performance at the first tier, their conceptual understanding became less consistent when reasoning and confidence dimensions were considered simultaneously. The decrease in percentages from the first tier to all four closed tiers indicates that some students who answered correctly at the initial level may still experience difficulties in maintaining scientifically consistent understanding across multiple representational and reasoning levels. Nevertheless, because the percentage of correct answers across all four closed tiers was above 30%, students' conceptual understanding can be categorized as moderate. If the data in Table 7 is represented as a graph illustrating the percentage of students' correct answers at the first tier, first and third tiers, and all four closed tiers, the results will be as shown in Figure 1.

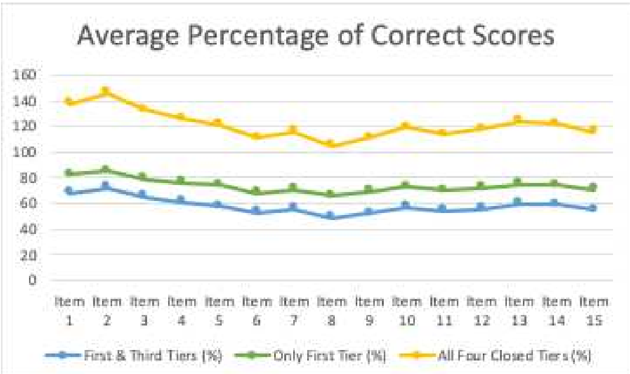

Figure 1. Average percentage of correct scores for grade 11 students in phase F at State Senior High School 13 Jambi City

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. Of the 33 students who worked on the five-tier diagnostic test, 17.4% or approximately 6 students were included in the lack of knowledge (LK) category on the material being tested. Meanwhile, students categorized as having scientific conception reached 50.8% or approximately 17 students, indicating that more than half of the students demonstrated scientifically acceptable conceptual understanding.

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In addition, 21.1% or approximately 7 students were included in the misconception category, 5.0% or approximately 2 students were included in the false positive category, and 5.8% or approximately 2 students were included in the false negative category.

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

Conception Categories	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14	Item 15	Mean (%)
False Negative	5.6	4.8	5.2	6.1	5.4	6.7	6.1	7.2	6.5	5.9	5.7	5.4	4.9	5.3	5.8	5.8
False Positive	4.2	3.7	4.5	5.1	4.9	5.6	5.3	6.1	5.8	5.4	4.8	5.2	4.6	4.9	5.0	5.0
Misconception	18	17	20	22	21	24	23	26	25	22	21	20	19	18	20	21.1
Lack of Knowledge	15	14	16	17	18	20	19	22	21	18	17	16	15	16	17	17.4
Scientific Conception	57.2	60.5	54.3	49.8	50.7	43.7	46.6	38.7	41.7	48.7	51.5	53.4	56.5	55.8	52.2	50.8

According [26], suggest using false positive and false negative probability estimates to evaluate the validity of test content. To establish content validity, these proportions are recommended to be below 10%. Based on the analysis results, the average proportion of false positive (5.0%) and false negative (5.8%) in this instrument were both below the suggested threshold, indicating acceptable content validity. Furthermore, the proportion of students categorized under misconception and lack of knowledge shows that some conceptual difficulties still exist, although the percentage of students with scientific conception was dominant. Based on the results of data processing on the diagnostic test that has been carried out, the misconception profile presented in Figure 2 was obtained.

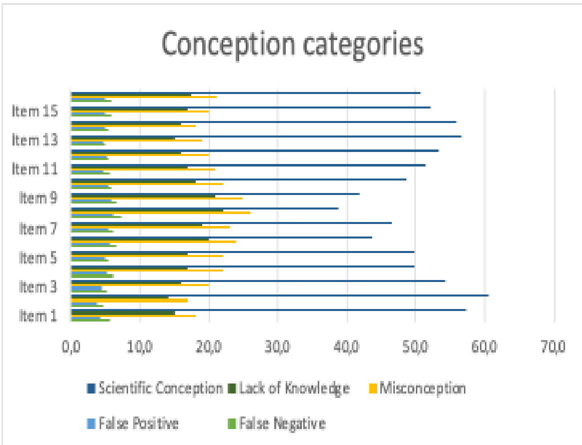

Figure 2. Percentage of student conceptions reviewed from False Negative, False Positive, Misconception, Lack of Knowledge, and Scientific Conception

Based on the data, it can be seen that the highest percentage of misconceptions occurs in test item number eight, reaching 26%, indicating that this item has the greatest proportion of students experiencing incorrect understanding. Meanwhile, the lowest misconception

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is found in test item number two, with a percentage of 17%. Overall, the average misconception rate is 21.1%, which suggests that misconceptions are still relatively high among students. In terms of the lack of knowledge category, the highest percentage is also observed in item number eight at 22%, while the lowest occurs in item number two at 14%, with an overall average of 17.4%. This indicates that, besides misconceptions, a considerable number of students also lack sufficient understanding of the concepts being tested. For false negative responses, the highest percentage appears in item number eight at 7.2%, while the lowest is in item number two at 4.8%, with an average of 5.8%. Similarly, false positive responses are highest in item number eight at 6.1% and lowest in item number two at 3.7%, with an average of 5.0%. On the other hand, the scientific conception category shows the highest percentage in item number two at 60.5%, indicating that most students answered correctly on this item. The lowest percentage is found in item number eight at 38.7%. The overall average of scientific conception is 50.8%, suggesting that only about half of the students demonstrate correct conceptual understanding. According to [36], misconceptions are considered significant if they exceed 10% of the sample. Therefore, in this study, misconceptions are present in all test items, as each item shows a percentage well above 10%, with the most critical occurring in item number 8.

The fifth tier, in the form of open-ended statements, serves as a source of qualitative information to further clarify students' understanding when answering tiers 1 to 4. Through these responses, students are able to express their reasoning, arguments, and thought processes more freely, allowing for a deeper analysis of whether their answers are based on correct scientific conceptions, partial understanding, misconceptions, or mere guessing. Therefore, the data obtained from tier 5 provide important support in interpreting the results of the previous tiers and in identifying the underlying causes of students' conceptions.

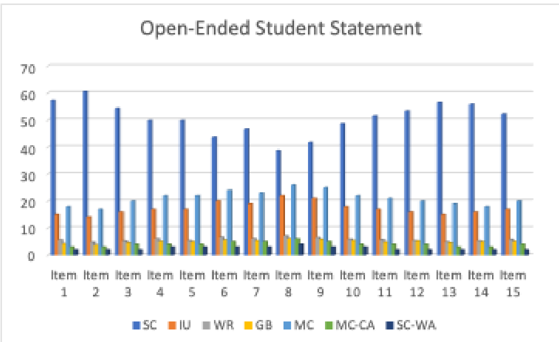

Figure 3. Open-ended student statement

The table presents the distribution of Tier-5 (open-ended student statements) across 15 items, categorized into seven types of explanations, namely Scientifically Consistent (SC), Incomplete/Uncertain (IU), Weak or Inconsistent Reasoning (WR), Guessing-Based (GB),

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Misconception (MC), Misconception Despite Correct Answer (MC-CA), and Scientifically Correct Despite Wrong Answer (SC-WA). Based on the data, Scientifically Consistent explanations (SC) dominate most items, with percentages ranging from 38.7% to 60.5%. The highest value occurs in Item 2 (60.5%), indicating that a large proportion of students are able to provide logically correct and scientifically accurate explanations. However, the percentage decreases in several items, particularly Item 8 (38.7%), suggesting that students experience more difficulty in explaining concepts correctly in certain contexts. Meanwhile, Misconception (MC) remains relatively high across all items, ranging from 17% to 26%, with the highest value found in Item 8 (26%). This indicates that a significant number of students still hold incorrect conceptual understandings, even when they are asked to explain their reasoning in an open-ended format. The Incomplete or Uncertain (IU) category also shows a consistent presence, with values between 14% and 22%. This suggests that many students have only partial understanding and are unable to fully articulate their reasoning. On the other hand, Weak or Inconsistent Reasoning (WR) and Guessing-Based explanations (GB) contribute smaller proportions, generally below 7%, indicating that fewer students rely on weak logic or guessing when providing explanations. Additionally, the categories MC-CA and SC-WA appear in smaller proportions, highlighting inconsistencies between students' answers and their explanations. MC-CA indicates that some students arrive at correct answers but still hold incorrect reasoning, while SC-WA shows that some students actually understand the concept but fail to select the correct answer. Overall, this table demonstrates that although scientifically correct explanations are dominant, misconceptions and incomplete understanding still play a significant role in shaping students' conceptions. It also highlights the importance of analyzing open-ended responses (Tier-5) to reveal deeper insights into students' thinking processes beyond objective answers.

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 [17].

Table 9. Description of misconceptions of the topic of elasticity and Hooke's law.

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Code	Item Selection	Misconception Description
M1	1.1 (B,C); 2.1 (A,A); 3.1 (A,A)	Students believe that a series spring system has a larger effective spring constant and thus a smaller oscillation period than a parallel system.
M2	2.1 (D,D); 3.1 (C,C)	Students assume that the oscillation period depends only on mass and is independent of the spring constant.
M3	3.1 (A,A); 3.1 (D,D)	Students think that smaller elongation directly results in faster oscillation without understanding the role of effective spring constant.
M4	4.1 (A,B); 4.1 (D,E)	Students believe that cross-sectional area does not affect elongation or that larger area leads to greater elongation.
M5	5.1 (C,C); 5.1 (A,B)	Students assume that spring arrangement (series or parallel) does not affect the force required for the same extension.
M6	6.1 (C,C); 6.1 (B,B)	Students think that the number of springs does not influence the total force or effective spring constant in a system.
M7	7.1 (B,A); 7.1 (D,D)	Students misunderstand elasticity by assuming objects remain elastic even after permanent deformation.
M8	8.1 (A,A); 8.1 (B,B); 8.1 (D,E)	Students do not understand Hooke's Law as a linear relationship, assuming force and extension are not proportional or not starting from zero.
M9	9.1 (B,B); 10.1 (B,B); 9.1 (D,D)	Students believe elongation depends on density or applied force only, not on Young's modulus.
M10	11.1 (B,B); 12.1 (A,B); 13.1 (B,B)	Students think that a larger Young's modulus leads to larger elongation or strain.
M11	12.1 (C,C); 12.1 (E,E)	Students assume that strain is independent of Young's modulus under the same stress.
M12	14.1 (B,B); 14.1 (D,D)	Students believe that the spring constant does not affect deformation (e.g., thickness change in springbed).
M13	15.1 (B,B); 15.1 (E,B)	Students assume that the spring constant changes with the mass applied instead of being a fixed property.

Based on the analysis presented in the table above, it was found that there are thirteen types of misconception descriptions in the topic of elasticity and Hooke's Law. Code M1 represents the first type of misconception, M2 represents the second type, and so on until M13, which represents the thirteenth type of misconception.

Each item selection is written in the form *(x.y (a, b))* which indicates the student's answer pattern. For example, item 1.1 (B, C) in M1 means that the misconception occurs in question number 1, where students chose option B in tier 1 (answer) and option C in tier 3 (reason). This combination reflects a specific misunderstanding of the concept being tested. Similarly, other codes group together answer patterns that indicate the same type of misconception across different items. From this classification, it can be seen that students' misconceptions are distributed across several subtopics, such as spring arrangement (series and parallel), elasticity properties, Hooke's Law, and Young's modulus. Each misconception code represents a consistent incorrect understanding that appears in multiple items with similar answer patterns.

Furthermore, based on the analysis of these misconception descriptions, the percentage of each misconception type can be calculated and then presented visually, as shown in the corresponding figure (e.g., Figure X). This percentage distribution helps to identify which misconceptions are most dominant among students and provides a basis for further instructional improvement. Then, based on the analysis of the misconception description, the percentage is obtained as shown in Figure 4.

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Misconception	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
Only First Tiers	10	6,7	6,7	6,7	6,7	6,7	6,7	10	10	10	6,7	6,7	6,7	7,7
First & Third Tiers	10	6,7	6,7	6,7	6,7	6,7	6,7	10	10	10	6,7	6,7	6,7	7,7
All Four Tiers	10	6,7	6,7	6,7	6,7	6,7	6,7	10	10	10	6,7	6,7	6,7	7,7

Figure 4. Percentage of descriptions of misconceptions based on the number of tiers

Figure 4 illustrates the percentage of misconceptions about elasticity and Hooke's Law classified by the number of tiers (Only First Tiers, First and Third Tiers, and All Four Tiers) across thirteen categories of misconceptions (M1 to M13). This figure shows a relatively uniform pattern in each tier category, indicating that the distribution of misconceptions is consistent across different levels of analysis.

Based on the data presented, the average percentage of misconceptions in the Only First Tiers category is 7.7%. Similarly, the average percentage in the First and Third Tiers category is also 7.7%, and the average percentage for All Four Tiers is 7.7%. These results indicate that the level of misconceptions identified remains stable regardless of the number of tiers used in the analysis. Overall, the percentage of misconceptions can be categorized as low, since the values are far below 30%.

This finding suggests that although misconceptions exist in various subtopics such as spring systems, elasticity properties, Hooke's Law, and Young's modulus their overall proportion is not dominant. However, the use of multi-tier diagnostic tests still plays an important role in identifying misconceptions more comprehensively. Even though the percentages appear similar, higher-tier analysis provides deeper insight into students' reasoning and confidence levels, allowing for more accurate identification of misconceptions.

Research relevant to this study shows that misconceptions in physics are often consistent across different contexts. Similar patterns have been found in previous studies, where students tend to misunderstand fundamental relationships, such as the effect of spring arrangement or the role of material properties like Young's modulus. However, many earlier studies focused mainly on identifying

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misconceptions without exploring their underlying causes.

The present study contributes to physics education by applying a multi-tier diagnostic approach to analyze students' misconceptions in elasticity and Hooke's Law. Although the fifth tier (source of conception) is not included in this table, the overall framework allows for deeper exploration of students' understanding compared to traditional assessments. This approach enables educators to not only detect misconceptions but also better understand how students construct their knowledge.

The practical implication of this study is that teachers can design more effective instructional strategies by addressing specific misconceptions identified in each category. For example, teachers can emphasize conceptual understanding of spring systems and material properties through experiments, visualizations, and problem-based learning. Nevertheless, this study has limitations, as it is based on a limited dataset and focuses only on one topic in physics. Therefore, further research is recommended to apply similar instruments to broader topics and larger populations, as well as to develop more practical tools, such as digital-based diagnostic systems, to facilitate faster and more efficient analysis.

CONCLUSION

This study successfully analyzed students' misconceptions on the topic of elasticity and Hooke's Law using a multi-tier diagnostic approach. The instrument applied in this study was able to identify students' understanding in a structured manner across several tiers, allowing misconceptions to be detected more comprehensively. The results showed that students still experienced difficulties in understanding key concepts, such as spring systems (series and parallel), Hooke's Law, elasticity properties, and Young's modulus. A total of thirteen types of misconceptions (M1–M13) were identified. However, the overall average percentage of misconceptions was 7.7%, which is categorized as low. This indicates that although misconceptions are present, they are not dominant among students. Furthermore, the analysis based on the number of tiers (Only First Tiers, First and Third Tiers, and All Four Tiers) showed relatively consistent percentages. This suggests that the distribution of misconceptions remains stable across different levels of analysis. Nevertheless, the use of multiple tiers is still important because it provides deeper insights into students' reasoning and helps distinguish between lack of knowledge and true misconceptions. Practically, this study contributes to physics education by providing a diagnostic framework that can help teachers identify specific misconceptions in elasticity and Hooke's Law. With this information, teachers can design more targeted instructional strategies, such as using experiments, visual representations, and conceptual discussions to improve students' understanding. However, this study has limitations, as it is based on limited data and focuses only on one topic. Therefore, the results cannot be generalized to a wider population. Future research is recommended to

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expand the use of this diagnostic instrument to other physics topics and larger samples, as well as to develop digital-based tools (e.g., web-based systems) to make the analysis more practical, efficient, and accessible.

REFERENCES

[1] 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.

[2] 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.

[3] 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

[4] 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.

[5] 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.

[6] 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.

[7] 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.

[8] 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).

[9] 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.

Jurnal Pendidikan Matematika dan IPA
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https://doi.org/10.37251/isej.v6i1.1379

[10] 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.

[11] 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

[12] 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.

[13] 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.

[14] 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.

[15] 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

[16] 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.

[17] 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.

[18] 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.

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

https://doi.org/10.22437/jiituj.v8i2.34159.

[19] 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.

[20] 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

[21] 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

[22] 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.

[23] 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.

[24] 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.

[25] 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.

[26] 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.

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

https://doi.org/10.1080/02635143.2017.1310094.

[27] 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.

[28] 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.

[29] 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.

[30] 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.

[31] 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

[32] 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.

[33] 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.

[34] 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.

[35] 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.

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

[36] 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.

[37] 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.

[38] 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.

[39] 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.

[40] 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

[41] 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.

[42] 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

[43] 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

[44] Miharja, M. A., Bulayi, M., & Triet, L. V. M. (2024). Realistic mathematics education: Unlocking problem-solving potential in students.*Interval: Indonesian Journal of*

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

Mathematical Education, *2*(1), 50-59. https://doi.org/10.37251/ijome.v2i1.1344

[45] 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.

[46] 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

[47] 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

[48] 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.

[49] 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.

[50] 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.

[51] 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.

[52] 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.

[53] 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.

[54] 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

[55] 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.

[56] 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.

[57] 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.

[58] 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

[59] 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.

[60] 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.

[61] 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

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

ecological teaching intervention in upper secondary schools. Ph*ysical Review Physics Education Research*, 17(2), 20132. https://doi.org/10.1103/PhysRevPhysEducRes.17.020132.

[62] 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.

[63] 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.

[64] 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.

[65] 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

[66] 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.

[67] 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.

[68] 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.

[69] 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

[70] Woitkowski, D. (2020). Tracing physics content knowledge gains using content complexity levels. *International Journal of Science Education*, *42*(10), 1585–1608.

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 2 (2026) h. 368-392

https://doi.org/10.1080/09500693.2020.1772520.

[71] 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