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Analysis of Students' Misconceptions Using Three-Tier Diagnostic Test on Straight Motion Material

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Abstract

This study aims to analyze the extent of misconceptions held by students at SMAN 3 Kuala Kapuas regarding the motion of objects and their causes. This study constitutes descriptive research. The methodologies employed for data collection included observation and testing. The instruments employed comprised both test and non-test instruments (questionnaires). The three-tiered diagnostic test was designed to ascertain the extent of student misconceptions. The non-test instrument employed was an interview instrument designed to ascertain the underlying factors contributing to the formation of erroneous beliefs among students. The tools employed consisted of test papers and structured interview protocols. The data pertaining to misconceptions were subjected to both quantitative and qualitative analysis, after which the percentage of students' misconceptions was elucidated through discussion. The population for this study comprised all students enrolled in Class X MIPA at SMAN 3 Kuala Kapuas, while the sample size consisted of 15 students. According to the analysis of the data, the average percentage of misconceptions among students at SMAN 3 Kuala Kapuas is 45.33%. The factors contributing to misconceptions among students include their abilities, the teaching methods employed by teachers, the interactions and communication between teachers and students throughout the learning process, and the student's learning styles. The implications of this study suggest that it influences the learning process and enhances the quality of student comprehension. Furthermore, it facilitates the development of superior instructional materials, such as incorporating illustrations, simulations, or straightforward experiments, which elucidate abstract concepts.

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INTRODUCTION

The comprehension of concepts is an essential competency in the study of physics. When students grasp concepts, they can effectively link one concept to another (Caleon & Subramaniam, 2010). A comprehensive conceptual understanding is essential in the educational process, as it equips students with the foundational skills necessary for critical thinking, effective communication, and problem-solving (Agustina et al., 2016; Prihandono et al., 2017; Rizkyanda et al., 2013). In the preliminary stage, students initially draw upon their everyday experiences, observations, cognitive processes, and linguistic abilities before acquiring physics concepts. The knowledge held by students at the outset frequently diverges from the comprehension attained by specialists. This inconsistency is identified as a misconception (Andriana et al., 2014). Pujayanto and Wakito assert that significant disparities exist in comprehension when teachers present new subjects that diverge from students' preconceived notions. Consequently, these discrepancies hinder students' ability to reconcile their ideas. The prevalence of misconceptions among students, which remain unrecognized by the students themselves, is expected to increase (Pujayanto & Waskito, 2007). Misconceptions among students significantly impede their ability to progress to more advanced material (Kirbulut & Geban, 2014). A continuous progression characterizes the process of comprehension in physics education. The presence of misconceptions, whether acknowledged or unacknowledged, can impede students' acquisition of new knowledge (Rahmi, 2013).

The term concept encompasses two distinct meanings: the first refers to a plan or outline of a letter. In contrast, the second pertains to an abstract notion or comprehension of a tangible concept (Sugiono, 2020). As Suhermiati (2015) stated, theory is the culmination of individual or collective thought systematically articulated to generate knowledge encompassing principles, rules, and concepts. As articulated by Suparno (2013), concepts are constructs of cognition that serve as the foundation for advanced cognitive processes, enabling the formulation of principles and practices.

Malikha and Amir assert that the terms "theory" and "concept" are distinct in meaning and application. The concept in question is broader in scope and will be interpreted in accordance with mutual consent. At this juncture, the concept is either distinctive or unparalleled. In this sense, the concept is known as perception or meaning (understanding). At this juncture, a theory can be defined as an individual's comprehension or interpretation of a particular subject matter. In essence, conception refers to the comprehension of a concept derived from the cognitive processes of each individual (Malikha & Amir, 2018; Primayoga et al., 2013).

The prior knowledge acquired by students frequently opposes the theoretical frameworks articulated by experts. Misconceptions are interpretations that diverge from the concepts recognized by experts (Suparno, 2013). Misconceptions are persistent inconsistencies or misunderstandings that are challenging to rectify and tend to endure over an extended period. Whether erroneous or divergent, misconceptions are challenging to rectify and tend to be perpetuated over extended durations (Jayantini et al., 2020).

Koze (in Suhermiati, 2015) stated that misconceptions refer to instances where students cultivate a comprehension of a subject yet fail to grasp its fundamental truths. Meanwhile, Ibrahim (as cited in Suhermiati, 2015) posits that skepticism constitutes a misinterpretation or perspective regarding a concept that, according to societal consensus, diverges from the notions deemed accurate and valid by experts. This divergence manifests as (a) conflicting viewpoints resistant to alteration and (b) continuity, which refers to the capacity for persistence. Altering this perspective is a challenging endeavor (Suhermiati, 2015)

Students develop erroneous beliefs as a result of both internal and external influences. Internal factors contributing to erroneous beliefs among students encompass their insufficient comprehension of more intricate concepts and their incapacity to establish connections between fundamental concepts and more advanced ones. External factors contributing to misconceptions include educational resources such as textbooks, teachers, and the Internet (Adrianto et al., 2022). Students' comprehension that remains unintegrated with scientific concepts is likely to result in misconceptions, which tend to be enduring and resistant to modification (Ozmen, 2011). Numerous misconceptions exist within material physics, particularly concerning the kinematics of linear motion, including the principles of uniform motion, differential motion, free fall, and upward mobility (Ratama, 2013). Students frequently encounter misconceptions in various discussions, including the following: 1) the assumption that displacement and distance are synonymous, 2) the belief that objects in continuous motion inherently possess a high speed, thereby implying that their acceleration is also elevated, and 3) the notion that negative speed does not exist, or signifies that the object is stationary, and 4) all entities are at rest without any acceleration (Artiawati et al., 2016).

Consequently, misconceptions are errors in comprehension exhibited by students regarding a particular concept, resulting in a student's understanding that diverges from the consensus established by experts in the field. Conceptual errors arise when students advance their cognitive abilities yet fail to recognize that the concepts they hold are fundamentally erroneous. Constructivist theory posits that most misconceptions and beliefs are established during childhood. According to Osborne (1983), it was observed that most elementary school students who had not received formal learning in electricity held the misconception that electricity diminishes as it traverses a light bulb. Consequently, as per the model, the input current exceeds the output current of the lamp (Faizah, 2016). Characterizes misconceptions as cognitive constructs or mental frameworks that are ingrained and endure within students' minds yet diverge from the perspectives held by experts. These misconceptions may hinder students' comprehension of natural phenomena and result in erroneous interpretations in their application (R & Tayubi, 2005).

Prior to assisting students in addressing their misconceptions, teachers must first comprehend the nature of those misconceptions. Suparno (2013) delineates various methodologies for identifying misconceptions, encompassing concept maps, multiple-choice assessments accompanied by open-ended reasoning, written essay examinations, diagnostic interviews, and classroom discussions. The examination of misconceptions regarding a material can be conducted through the utilization of a diagnostic assessment. A frequently employed instrument for diagnosing misconceptions in educational materials, as evidenced in various research studies, is the three-tier diagnostic test (Kahraman, 2019; Laeli et al., 2023; Mubarokah et al., 2018; Resbiantoro et al., 2022; Turkoguz, 2020). This diagnostic assessment can reveal students' comprehensive understanding, encompassing their reasoning abilities and levels of self-confidence. Furthermore, this test functions as a self-evaluation tool, enabling students to identify their weaknesses, which can be addressed to enhance their conceptual comprehension (Prodjosantoso et al., 2019). According to the perspectives of these experts, it is evident that the three-tier diagnostic test offers distinct advantages over other forms of multiple-tier assessments, as it facilitates a more comprehensive exploration of students' understanding and misconceptions. The assessment is structured into three distinct layers: the selection of answer alternatives, the rationale underlying the chosen answers, and the degree of confidence associated with the provided responses. This supplementary layer enables the teacher to ascertain the student's response and comprehend their reasoning and degree of confidence regarding that response. Consequently, the assessment can identify misconceptions with greater precision, differentiating between genuinely mastered knowledge and mere conjecture and furnishing more accurate data to inform the development of more effective educational interventions.

The innovation of the three-tier diagnostic test research resides in its more holistic methodology for discerning students' comprehension and misconceptions. This test evaluates cognitive abilities via multiple-choice responses and investigates the rationale underlying the answers and the degree of student confidence in their selections. Utilizing this methodology, the three-tier diagnostic test demonstrates a novel approach that can identify misconceptions that may elude detection by conventional assessments or two-tier tests. This innovation represents a substantial advancement in creating more precise educational assessment instruments, enabling teachers to formulate more targeted and effective learning strategies grounded in a comprehensive understanding of students' cognitive frameworks. In light of these issues, the author contends that it is imperative to administer a diagnostic test to ascertain the presence of any misconceptions regarding physics that students may hold about object motion. This is significant as the concept of object motion is the foundation for students' comprehension of Newton's laws of motion. As an initial phase, the research concentrated on the kinematics of one-dimensional motion, commonly referred to as linear motion.

METHODS

The research methodology employed is a mixed methods approach, which integrates both quantitative and qualitative methods within the research process. This combination aims to yield comprehensive, valid, reliable, and thorough data (Creswell et al., 2007). This mixed-methods research employed an explanatory sequential design, a methodological framework that initiates the collection of quantitative data to discern specific trends or patterns. Subsequently, it advanced to collecting qualitative data to furnish a more profound explanation or comprehension of the quantitative results. The application of mixed methods in this study entailed executing a diagnostic test within the quantitative framework. Students responded to the assessment and provided justifications, accompanied by their respective confidence levels. In the qualitative methodology, students were interviewed to gather data regarding the underlying causes of misconceptions.

According to Usman et al. (2006), the population for each study must be distinctly delineated, specifically in terms of the magnitude of its constituent members. The population for this research comprised all students from Class X MIPA at SMAN 3 Kuala Kapuas, specifically those who had engaged with the material on linear motion, totaling 15 students. The saturated sample method is a sampling technique in which every member of the population is utilized as a sample. Saturated sampling was employed due to the limited size of the population (Sugiyono, 2015).

Sugiyono (2015) stated that non-probability sampling is a methodology in which not all elements and members of the population possess an equal likelihood of being chosen as part of the sample. The nonprobability sampling technique, referred to as saturated sampling, involves the inclusion of all members of the population in the sampling process. This procedure is conducted when the population is limited to fewer than 30 individuals (Sani & Masyhuri, 2010).

The instrument employed in this study was a three-tier diagnostic test that incorporates open-ended reasoning alongside options for respondents to indicate certainty or uncertainty. This assessment is designed to identify the misconceptions that may arise among students. The instrument was adapted from research conducted by Ratama (2013) and possessed content validity and a grammatically sound format. It was accompanied by a statement affirming that no revisions were necessary, thus permitting its use in its current form. Diagnostic test tool indicators are listed in Table 1.

Table 1 Indicators of the diagnostic test instrument

No.	Question indicator	Question No.
1	Identify and distinguish between distance and displacement	1,2
2	Identify and differentiate between speed and position	3
3	Identify and differentiate between velocity and acceleration	4,5
4	Identify and differentiate between the velocity and acceleration of an object when it reaches maximum height	6,7
5	Identify and distinguish between two objects of different masses dropped simultaneously	8,9,10

Misconceptions may be discerned through implementing a three-tier diagnostic test, utilizing multiple-choice questions pertinent to high school linear motion. In implementing a three-tier diagnostic test, multiple-choice questions are structured to encompass three distinct response levels. The initial level consists of multiple-choice questions of a general nature. The second level pertains to the rationale behind the students' selections at the first level. Finally, the third level assesses the students' confidence in their responses to the two preceding levels. The students' conceptual comprehension levels, as assessed by the three-tier diagnostic test, are delineated in Table 2.

Table 2 Category of students' comprehension level based on the three-tier diagnostic test

Answer	**Reason**	**Confidence**	**Category**
Correct	Correct	Sure	Understand the concept
Correct	Wrong	Sure	Misconceptions
Wrong	Correct	Sure	
Wrong	Wrong	Sure	
Correct	Wrong	Not sure	Does not understand the concept
Wrong	Correct	Not sure	
Correct	Correct	Not sure	
Wrong	Wrong	Not sure	

(Jumini et al., 2017)

The researchers undertook the following steps to conduct a thorough analysis of the acquired data: (a) examined student responses by correlating multiple-choice results with the reasons and beliefs of students, categorized according to their levels of understanding as indicated by the three-level diagnostic test; (b) organized and classified students' responses of understanding, lack of understanding, and misunderstanding; (c) computed the percentage of misunderstanding exhibited by students for each question; and (d) formulated conclusions based on the data, presenting them in the form of misunderstanding profiles and corresponding percentages of misunderstanding.

RESULTS AND DISCUSSION

The study was conducted by administering a diagnostic test comprising ten questions, structured at three levels, to identify students' misconceptions regarding the principles of linear motion. Each inquiry students present is intended to elicit responses grounded in their knowledge. Students should articulate the rationale behind their queries, demonstrating their comprehension and insights acquired throughout the educational process. There exists a degree of assurance in the selection of responses and the provision of transparent justifications, particularly in assessing the robustness of students' comprehension.

The identification of misconceptions was conducted through a three-tier diagnostic test designed to classify students into three categories: those who comprehended the concept, those who harbored misconceptions, and those who did not grasp the concept. Not all errors in student responses are classified as such; they may arise from a lack of comprehension regarding the subject matter. The graph of the percentage of misconceptions of each student on all questions is shown in Figure 1.

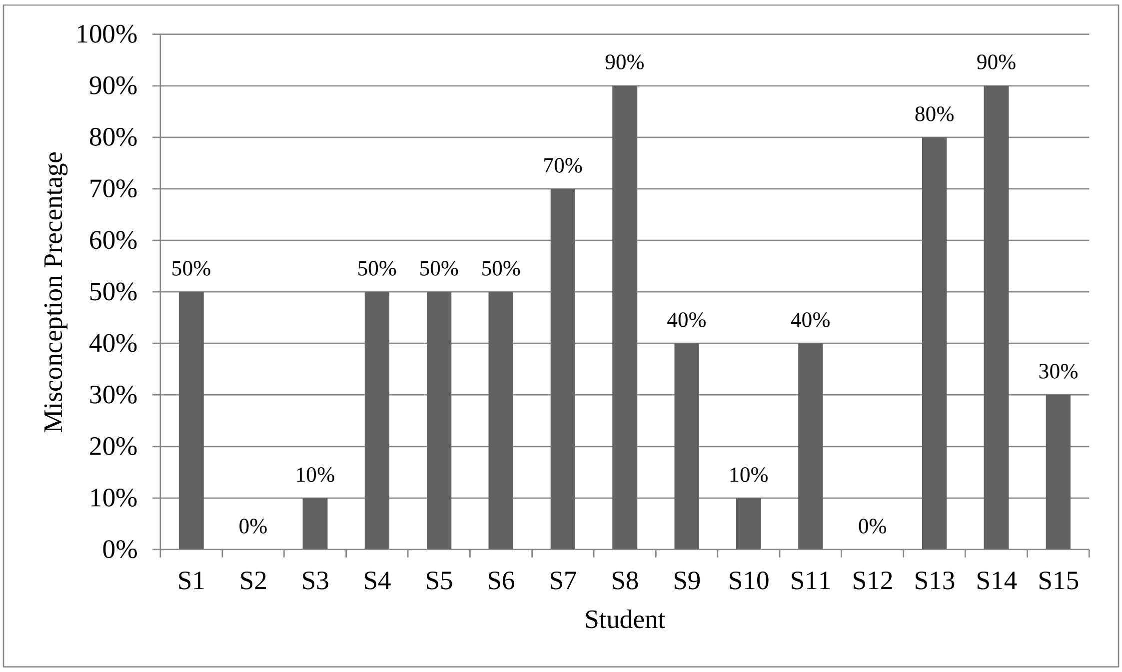

Figure 1 Graph of the percentage of misconceptions of each learner on all questions

The graph of the percentage of student misconceptions on each question is shown in Figure 2.

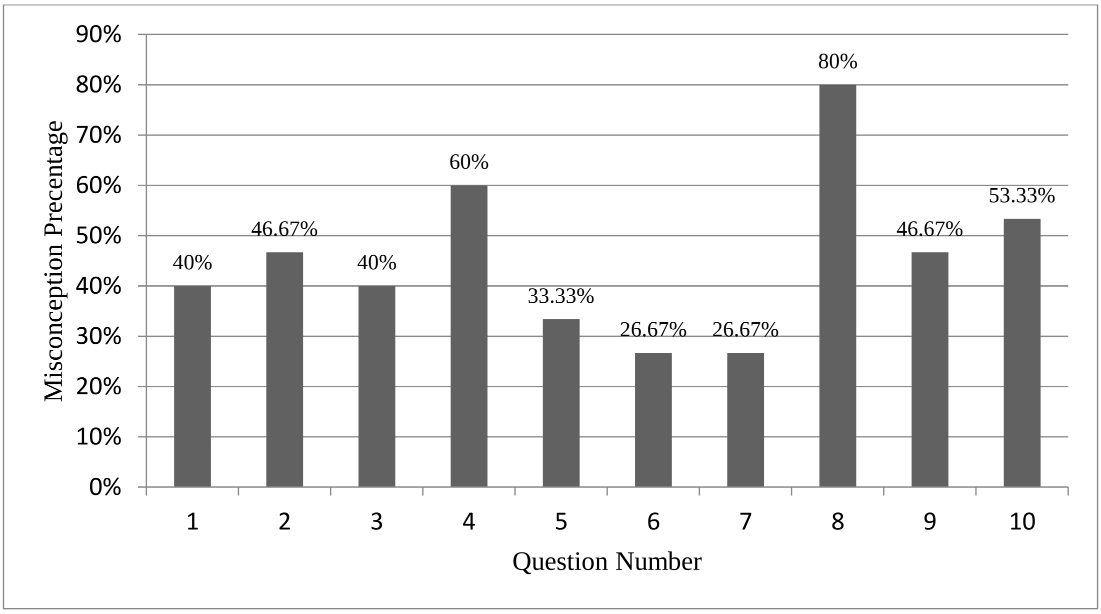

Figure 2 Graph of the percentage of students' misconceptions in each question

Table 1 shows that students have numerous misconceptions about linear motion. As demonstrated by students, the following serves as an exemplary response to the criterion of differentiating between velocity and acceleration.

Question: What is the relationship between the acceleration and velocity of an object moving in a straight line?

Answer: If the acceleration is fixed, the speed does not change.

Question:	How confident you are in that answer
Answer:	Pretty sure because I have studied in class

Certain questions within the interview questionnaire were subsequently corroborated by the test instrument employed, as elucidated as follows.

The level of students' misconceptions regarding the material of linear motion

The average percentage of misconceptions, which stands at 45.33%, is very high, indicating that nearly all students encounter misunderstandings regarding a specific problem. Consequently, it is imperative to identify erroneous beliefs and rectify misconceptions. If not managed appropriately, it may adversely affect the adoption of novel concepts pertaining to the appropriate motion material. Altering erroneous beliefs presents significant challenges as individuals construct their understanding of knowledge through their personal experiences. Once an individual acquires knowledge, it becomes challenging to inform them that their understanding may be flawed; one can only encourage them to reconsider their misconceptions. Consequently, altering an erroneous belief involves formulating a new concept that more accurately elucidates the experience.

The analysis of the study findings indicates that this study aligns with the perspective of Hakim et al. (2012), which posits that the three-tier test is an effective tool for identifying misconceptions and differentiating them from the lack of knowledge through a straightforward methodology. Nonetheless, a limitation of this test is that students are permitted to select their level of confidence solely when determining their answers and justifications for each question. At this level of confidence, it is not feasible to ascertain whether students possess varying degrees of confidence in selecting the correct answer.

Factors Contributing to Students' Misconceptions

Students may encounter misconceptions due to a multitude of factors. To ascertain the underlying causes of misconceptions, a question-and-answer process or an interview is conducted with students. Interviews were administered to students according to the degree of their misconceptions. The interview reveals that students' misconceptions stem from preexisting notions derived from their personal experiences, compounded by insufficient clarification from the teacher, which necessitates autonomous learning on the part of the students.

In accordance with the findings of Tayubi (2005) and Fakhriyah (2021), misconceptions may arise from everyday interactions with the natural environment. These experiences can lead to the formation of intuitions that are not necessarily accurate in students' minds. Preconceptions or prior knowledge regarding physics concepts, which students develop through informal learning to comprehend their everyday experiences, significantly contribute to formulating scientific theories (Maretta et al., 2023). The preconceptions held by students, many of which are erroneous, frequently impede the development of scientific concepts (Bangun et al., 2019). Misconceptions also arise among students who engage with abstract conceptual material that lacks tangible reality, resulting in a lack of clarity in their comprehension of the concept (Haryono et al., 2021; Khandagale & Shinde, 2021).

How students acquire knowledge also contributes to the development of misconceptions among them. According to the data from interviews, students consistently recall instances of uncertainty. Consequently, students are unfamiliar with applying the concepts they acquire to address problems and understand their interrelationships. According to Wahyudiono (2023), learning outcomes derived from memorization and subliminal processes tend to be transient, and the underlying concepts may be inadequately comprehended. This may hinder their ability to cultivate essential problem-solving skills and address various forms of problem development, leading to student misunderstandings (Agrin et al., 2018).

Research Limitations

The researchers' study is invariably accompanied by limitations and challenges that may hinder the attainment of optimal outcomes anticipated by the researchers. The limitations of this study include administering the test online through Google Forms, which does not impose a time constraint on the collection of responses. This lack of temporal restriction permits students to submit answers that may not accurately reflect their comprehension, as they can search for answers on the internet or collaborate with their peers during the assessment.

This study faced numerous challenges and limitations in its execution. The challenges and shortcomings experienced included difficulty securing research authorization from the school, primarily due to the challenges associated with locating the principal. Consequently, this impediment resulted in a delay in the timely execution of the research. Another challenge was the constrained timeframe, which coincided with the week's examination schedule. This limitation affected the availability of students for interviews intended to address the uncertainties they experienced. Furthermore, the online format complicated communication with certain students.

CONCLUSION

The level of misconceptions among students regarding the motion of the lusus falls within a sufficiently high category, with an average percentage of 45.33%, according to the research conducted through data collection at SMAN 3 Kuala Kapuas and the subsequent analysis utilizing the Three-Tier Diagnostic Test. Furthermore, the study identified several contributing factors to these misconceptions, including students' preconceptions, the effectiveness of the instructional methods employed, and the overall inadequacy of the students' learning strategies. The results of this study are intended to serve as reference material for subsequent research aimed at addressing and enhancing the comprehension of students' misconceptions.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest in this study.

AUTHOR CONTRIBUTIONS STATEMENT

All of the authors have contributed to the conceptualization, methodology, formal analysis, investigation, and writing this article.

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