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The Three-Tier Test Approach to Measuring Misconceptions in High School Physics: Focus on Work and Energy

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ABSTRACT

This study aims to identify misconceptions experienced 10th grade students on the subject of Work and Energy using a three-tier test. The type of research used is quantitative descriptive. The data collection instrument was a three-tier test consisting of 10 questions, which had been tested and found to have a validity of 0.96 and reliability (Cronbach's Alpha) of 0.81, making it suitable for measuring students' conceptual understanding. There were 34 students in this study, with purposive sampling used as the sampling technique. The data were obtained through Google Forms and analyzed statistically to identify the level of students' misconceptions. The results showed that the highest misconception occurred in the subconcept of work (79.41%), followed by kinetic energy and potential energy (55.88%), and the law of conservation of energy (41.18%). These findings are expected to provide insight for educators and curriculum developers in designing more effective learning strategies, thereby helping students overcome misconceptions and improve their understanding of physics concepts. Thus, it can be concluded that most students still have misconceptions about the concepts of Work and Energy, requiring learning strategies that emphasize strengthening conceptual understanding.

INTISARI

Penelitian ini bertujuan untuk mengidentifikasi miskonsepsi yang dialami oleh siswa kelas X pada materi Usaha dan Energi menggunakan three-tier test. Jenis penelitian yang digunakan adalah deskriptif kuantitatif. Instrumen pengumpulan data berupa three-tier test yang terdiri atas 10 butir soal, yang telah diuji dan dinyatakan memiliki validitas sebesar 0,96 dan reliabilitas (Cronbach's Alpha) sebesar 0,81, sehingga layak digunakan untuk mengukur pemahaman konseptual siswa. Responden dalam penelitian ini berjumlah 34 siswa, dengan teknik pengambilan sampel menggunakan purposive sampling. Data diperoleh melalui Google Form dan dianalisis secara statistik untuk mengidentifikasi tingkat miskonsepsi siswa. Hasil penelitian menunjukkan bahwa miskonsepsi tertinggi terjadi pada subkonsep usaha (79,41%), diikuti oleh energi kinetik dan energi potensial (55,88%), serta hukum kekekalan energi (41,18%). Temuan ini diharapkan dapat memberikan wawasan bagi pendidik dan pengembang kurikulum dalam merancang strategi pembelajaran yang lebih efektif, sehingga dapat membantu siswa mengatasi miskonsepsi dan meningkatkan pemahaman terhadap konsep-konsep fisika. Dengan demikian, dapat disimpulkan bahwa sebagian besar siswa masih mengalami miskonsepsi pada konsep Usaha dan

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Energi, sehingga diperlukan strategi pembelajaran yang menekankan pada penguatan pemahaman konseptual.

A. Introduction

Rapid advances in knowledge and technology have made various human activities in daily life easier. Physics, as one of the branches of Natural Sciences, plays a fundamental role in the development of Science and Technology [1]. Therefore, it is important for students to have a good understanding of physics concepts in order to keep up with the dynamics of technological development. However, physics is known as a subject that requires a high level of abstraction and mastery of mathematics as a tool, so many students find it difficult to learn. This often leads to students struggling with physics if their initial abilities are insufficient [2]. In line with the importance of physics in life and technological development, a strong conceptual understanding is necessary for students to master and apply physics concepts correctly.

Conceptual understanding is the main foundation in physics learning. Misconceptions or understandings that are not in line with generally accepted scientific concepts can hinder the learning process of students. These misconceptions often originate from incomplete initial understandings and then become firmly embedded in the cognitive structure of students, thereby hindering the learning of advanced concepts [3]. Pratiwi and Permadi [4] state that misconceptions often arise because students are unable to connect abstract concepts with the real-world contexts they experience in their daily lives, thus forming incorrect alternative ideas.

Good conceptual understanding is very important in physics learning so that students can relate concepts to phenomena that occur in their surroundings. Yuliati et al. [5] explain that the application of authentic problem-based learning can improve critical thinking skills and help students understand physics concepts in depth, thereby reducing the emergence of misconceptions. Meanwhile, Maliada et al. [6] emphasize that misconceptions are beliefs that are deeply ingrained and form a stable cognitive structure in students' minds, even though they contradict correct scientific concepts. Understanding physics concepts is very important for explaining various physical phenomena in everyday life and in more complex scientific contexts. Personal experiences or daily activities can also influence students' thinking and form conceptual patterns that are not always in line with scientific principles [7]. One example that is often found is students' misconceptions about work and energy, which is the focus of this study.

One of the topics in physics that most often causes misconceptions is Work and Energy. This is due to the complex concepts involved, such as the relationship between force, displacement, kinetic energy, potential energy, and the law of conservation of mechanical energy [8] [9]. These concepts require not only theoretical understanding, but also the ability to apply them in real-life contexts, which often poses a challenge for students. Utami and Rohmi [10] found that more than 70% of

students had misconceptions about the concept of the law of conservation of mechanical energy, and about 57% of students had misconceptions about the concept of work. These findings emphasize the importance of a diagnostic approach to identify and address student misconceptions early on.

Based on previous research findings and to obtain an initial picture of the condition of students at the school where the research was conducted, the researcher conducted an interview with one of the physics teachers. From the interview results, it was found that students had difficulty understanding the material on work and energy, especially the concept of potential energy. The teacher also admitted that he was not aware of the misconceptions that often occur in physics learning, including on this topic. In addition, the teacher had never conducted diagnostic tests to find out whether students truly understood the concepts or had misconceptions. If there were students who scored below the Minimum Passing Grade in physics exams, the teacher would only provide additional guidance by asking students to repeat the exam questions without identifying the causes of their conceptual difficulties.

One approach that can be used to effectively identify misconceptions is to use diagnostic tests [11]. Three-level diagnostic tests are better than two-level models because they provide more in-depth information [12]. This test consists of three parts: (1) answers to conceptual questions, (2) the reasoning behind those answers, and (3) the level of confidence students have in their answers [12]. This test allows educators to distinguish between stable misconceptions, ignorance, and lucky guesses. Pratama & Istiyono [13] showed that this test is able to identify students' misconceptions with higher accuracy and provide valid and reliable diagnostic information. In addition, the study also revealed that misunderstandings are not limited to one topic, but spread to various concepts in physics. The three-tiered test can comprehensively map students' understanding categories, ranging from fully understanding the concept to not understanding it at all. This tool can be used by teachers to design more targeted learning interventions [14].

The use of a three-tier test in this study was chosen because it is simpler and more efficient than a four-tier test, yet still capable of providing in-depth conceptual information relevant to the research objectives [15]. Several previous studies have also shown that although the four-tier test is capable of providing an additional classification in the form of confidence in reason, the instrument has a high level of technical complexity, making it less efficient to apply in a school learning context [16]. Thus, the use of a three-tier test is considered more appropriate and proportional to effectively identify students' misconceptions while maintaining practicality in its implementation [17]. Based on this background, this study was conducted with the aim of identifying misconceptions experienced by 10th grade students on the topic of Work and Energy using a three-tier test.

B. Method

This study uses a quantitative descriptive approach. The purpose of this study is to identify misconceptions experienced by students regarding the concepts of work and energy. The research subjects consisted of 34 tenth-grade students, including 14 male students and 20 female students. Previously, students had studied work and energy material, but had never taken a three-tier test. The instrument used to measure misconceptions consisted of 10 three-tier test questions related to work and energy material. The three-tier test instrument used in this study was developed by the researcher and distributed online via Google Form to improve the efficiency of the data collection process and adapt to the characteristics of 21st-century learning. This is in line with the view of Jalinus et al. [18], who stated that the integration of digital technology in the learning and assessment process can increase student engagement and the effectiveness of measuring conceptual understanding.

The questions in this three-level test were designed in three levels. The first level contained students' responses or answer choices to measure their understanding of the concepts, the second level contained the students' reasons for choosing the answers in the first level, and the third level showed the students' level of confidence in their chosen answers. This instrument obtained a validity score of 0.96 and a Cronbach's Alpha reliability coefficient of 0.81, indicating that the instrument is valid and reliable for diagnosing students' misconceptions on the subject of work and energy.

The data analysis process was carried out by the researcher through several stages, as follows: (1) Analyzing students' answers between confidence responses, multiple-choice answers, and reasons aligned with categories related to the level of understanding in the diagnostic test; (2) Classifying students' answers into categories of understanding, not understanding, and misconceptions; and (3) Summarizing the data obtained with profiles and percentages of misconceptions

Table 1. Categories in the Three-tier test

Category	Tier 1	Tier 2	Tier 3
Understand	True	True	Convinced
Not Understand	True	True	Not Convinced
	False	False	Not Convinced
	True	False	Not Convinced
	False	True	Not Convinced
Misconception	False	True	Convinced
	True	False	Convinced
	False	False	Convinced

Source: Sopian, H. [19]

C. Result and Discussion

Based on the results of the three-tier test, it can be seen that the percentage of students with the highest level of understanding was found in question number 2 of the subconcept work, which was 52.94%, while the percentage of students with the highest misconception was found in question number 1 of this subconcept, which was 79.41%. In the energy subconcept, the highest percentage of students with the highest level of understanding was found in question number 6, at 35.29%, while the highest percentage of misconceptions was found in question number 8 of this subconcept, at 55.88%. Additionally, in the subconcept of the law of conservation of energy, the highest number of misconceptions was found in question number 9, at 41.18%. This data can be seen in Table 3.

Table 3. Test Results with Three-tier test

Subconcept	Question No.	Student Answer Category (%)		
		Understand	Not Understand	Misconception
Work	1	5.88	14.71	79.41
	2	52.94	20.59	26.47
	3	41.18	11.76	47.06
	4	35.29	20.59	44.12
	Average	33.82	16.91	49.27
Kinetic Energy and Potential Energy	5	32.35	20.59	47.06
	6	35.29	20.59	44.12
	7	29.41	20.59	50.00
	8	14.71	29.41	55.88
	Average	27.94	22.79	49.27
Law of Conservation of Energy	9	32.35	26.47	41.18
	10	32.35	32.35	35.29
	Average	32.35	29.41	38.24

The indicators in this study aim to measure students' understanding of subconcepts in the subject of Work and Energy. Students are asked to interpret images of negative work, classify examples of work, and summarize the concept of work. In addition, students are expected to be able to calculate power, explain the factors that affect kinetic energy, and provide examples of its application in everyday life. Understanding of potential energy, the relationship between kinetic and potential energy, and the law of conservation of energy is also measured, including conclusions regarding the law of conservation of mechanical energy.

Subconcept Work

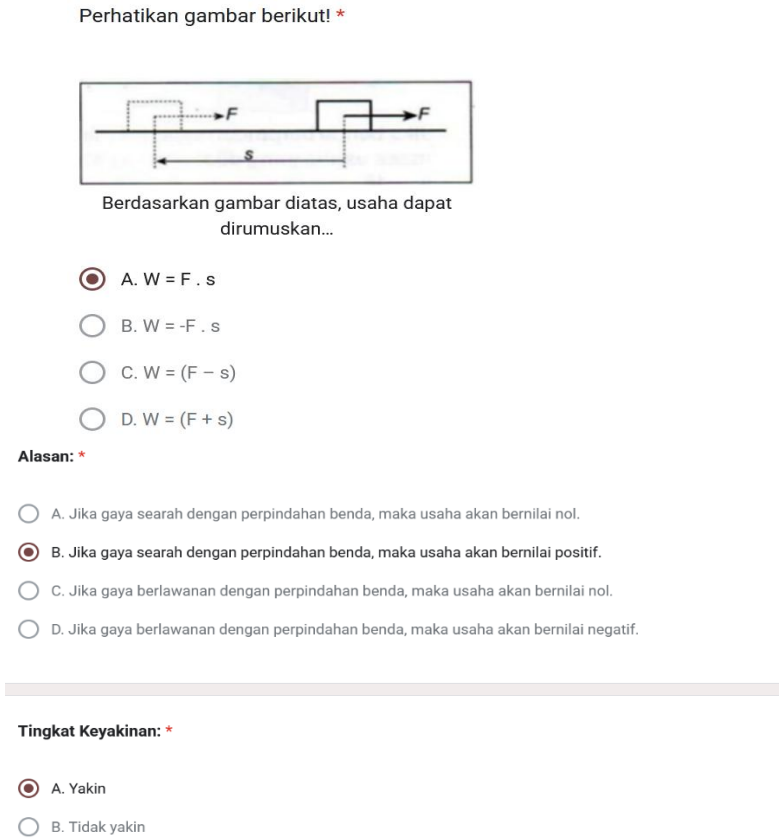

Figure 1. Student's Asnwer & Argument in Subconcept of Work

Based on the results of the study, it was found that 79.41% of students had the highest misconception on question number 1 in the subconcept of work with the question indicator interpreting an image of negative work. Many students chose option A (W = F.s) because they understood that "if the force is in the same direction as the displacement of the object, then the work will be positive." This is likely due to students' lack of understanding of the visual meaning of the image, particularly the direction of the force vector and displacement, leading to errors in interpreting the concept of negative work. However, the more accurate understanding is that "if the force is opposite to the direction of the object's displacement, then the work will be negative." Therefore, the correct answer is B (W = -F. s). This is supported by the research of Maison et al.[8], which found that the highest misconceptions also occur in the concepts of work and potential energy, with one of the students' errors being in interpreting the direction of the force relative to the displacement. Another study by Utami & Rohmi [10] also showed that 57% of students experienced similar misconceptions due to inaccuracies in understanding the relationship between the direction of the force and the displacement.

Subconcepts of Kinetic Energy and Potential Energy

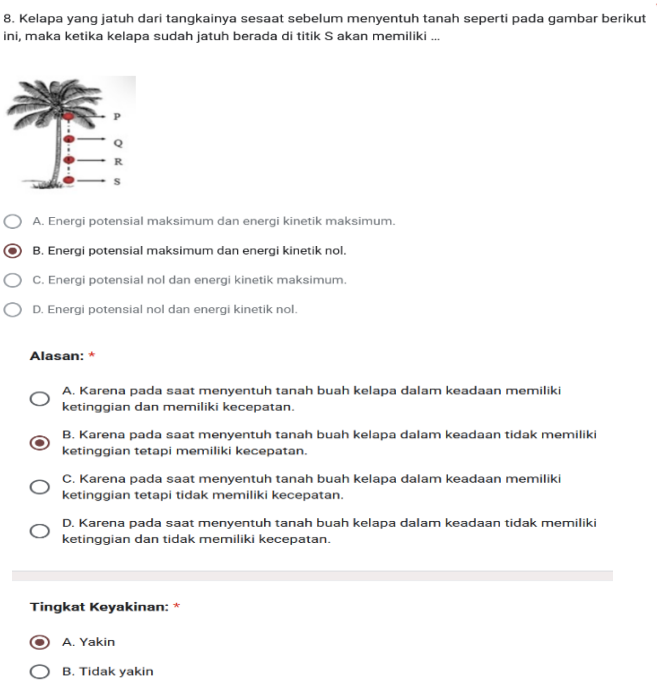

Figure 2. Student's Answer & Argument in Subconcepts of Kinetic Energy and Potential Energy

In the subconcepts of kinetic energy and potential energy, the results showed that 55.88% of students had misconceptions on question number 8, with the question indicator analyzing the relationship between potential energy and kinetic energy. Most students chose option B (maximum potential energy and zero kinetic energy). Students assume that when a coconut hits the ground, it has no height but has velocity. This is likely because students did not fully understand the conversion of energy from potential energy to kinetic energy, nor were they able to accurately relate physical events to theoretical concepts. This understanding needs to be corrected, as when the coconut hits the ground, it no longer has height or velocity. The correct answer choice is C, which states that "potential energy is zero and kinetic energy is maximum." Utami & Rohmi [10] note that misconceptions are also common in the concepts of potential, kinetic, and mechanical energy, with a pre-learning misconception rate of 43%.

Subconcept of the Law of Conservation of Energy

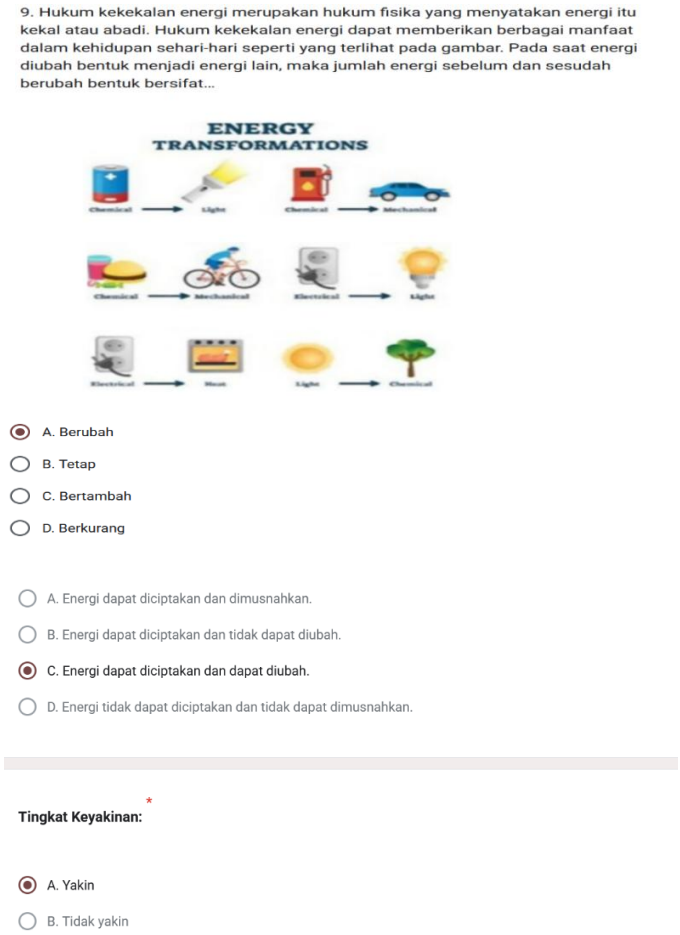

Figure 3. Student's Answer & Arguments in Subconcept of the Law of Conservation of Energy

In the subconcept of the law of conservation of energy, the results of the study show that 41.18% of students had misconceptions on question number 9, which asked them to interpret the law of conservation of energy in the form of a picture, with many students choosing option A (Changed). Students incorrectly assumed that energy can be created and changed. This is likely because students interpret energy sources such as batteries or food as creating new energy, which is then converted into light energy in flashlights or kinetic energy in the body. For example, in the picture of food, students think that food creates mechanical energy when a person is active, rather than understanding that the chemical energy in food is only converted into kinetic energy. This understanding indicates that students have not grasped the fundamental principle of the Law of Conservation of Energy, which states that energy cannot be created or destroyed but only transformed. The correct answer choice is B (Remains the Same). Maison et al. [8] also revealed that misconceptions commonly occur in understanding

the relationship between mechanical energy, potential energy, and kinetic energy. Students emphasized that these errors often arise due to a lack of reinforcement in connecting various forms of energy. Additionally, the three-tier instrument developed by Pratama & Istiyono [20] can identify misconceptions more accurately because it can distinguish between ignorance and misconceptions. This instrument also confirms that misconceptions remain high on the topic of energy and need to be addressed with more in-depth conceptual evaluation.

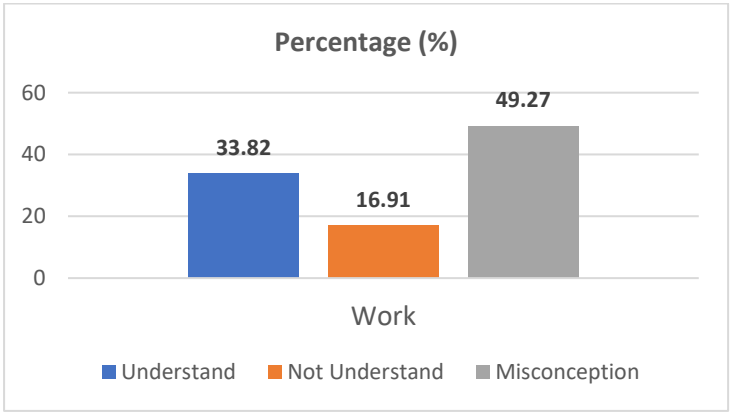

Figure 4. Percentage of Student Categories in the Subconcept Work

Figure 4 shows the percentage distribution of students' understanding of the subconcept of work based on the results of the three-tier diagnostic test. The data shows that an average of 49.27% of students have misconceptions, 16.91% do not understand the concept, and only 33.82% of students truly understand the concept of work. The high percentage of misconceptions indicates that more than half of the students have an incorrect understanding of the basic concept of work. One of the most common misconceptions is the assumption that work depends solely on the force applied, without considering the distance traveled. Students often think that the greater the force applied, the greater the work done, whereas work is also influenced by the distance traveled by the object.

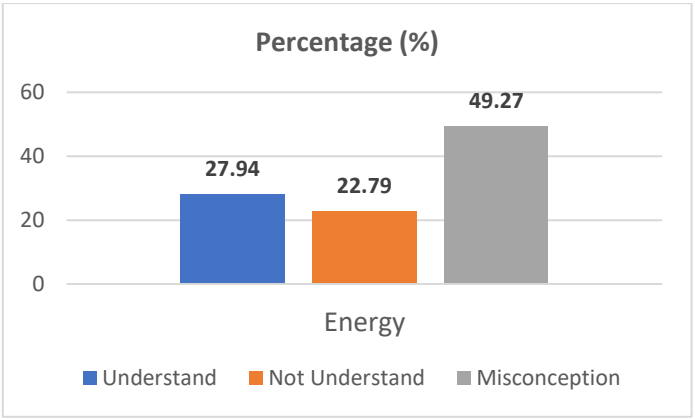

Figure 5. Percentage of Student Categories in the Subconcepts of Kinetic Energy and Potential Energy

Figure 5 shows the percentage distribution of students' understanding of the subconcepts of Kinetic Energy and Potential Energy based on the results of the three-tier diagnostic test. The data shows that an average of 49.27% of students have misconceptions, 22.79% do not understand the concept, and only 27.94% of students truly understand the concepts of kinetic energy and potential energy. The high percentage of misconceptions indicates that students struggle to understand the various forms of energy and how energy can transform from one form to another. One common misconception is the belief that energy exists only in specific forms, such as kinetic energy or potential energy, without realizing that energy can change forms and that all forms of energy are interconnected. This misconception can hinder students' understanding of more complex physics concepts, such as the laws of thermodynamics and the application of energy in everyday life.

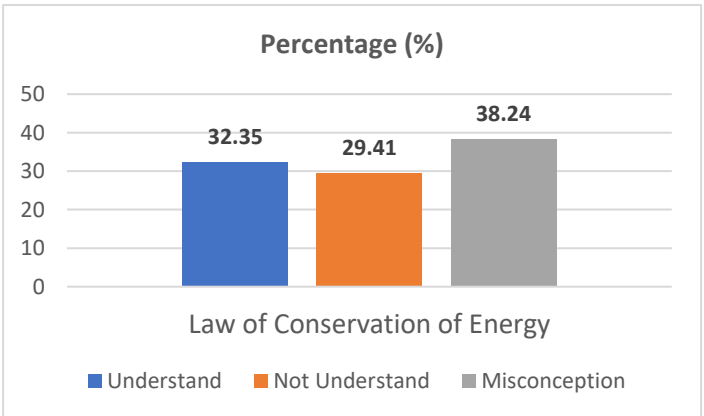

Figure 6. Percentage of Student Categories in the Subconcept of the Law of Conservation of Energy

Figure 6 shows the percentage distribution of students' understanding of the subconcept of the Law of Conservation of Energy based on the results of the three-level diagnostic test. Based on these results, it was found that an average of 38.24% of students had misconceptions, 29.41% did not understand the concept, and only 32.35% of students truly understood this concept. The analysis was conducted using quantitative descriptive methods with the application of descriptive statistics. The test results were analyzed to obtain the mean, the percentage of each understanding category, and the frequency distribution for each question item.

The average total score of the students showed that the level of conceptual understanding was still relatively low, with a standard deviation of 0.15, indicating a fairly high variation in understanding among students. This analysis provides a more comprehensive quantitative picture of the patterns of students' misconceptions about the concept of the Law of Conservation of Energy.

Although the level of misconception is lower than other subconcepts, this percentage still shows that more than one-third of students have a misconception about the basic principle that energy cannot be created or destroyed, but can only be converted from one form to another. One common misconception is the belief that energy can “disappear” in a process, when in fact energy only transfers or changes form. Thus, these results emphasize the importance of applying a more contextual and phenomenon-based learning approach so that students can understand the principle of conservation of energy more deeply.

D. Conclusion

The results of the study indicate that the level of misconceptions among 10th grade students regarding work and energy is still relatively high. The highest level of misconceptions was found in the subconcept of work at 79.41%, followed by kinetic energy and potential energy at 55.88%, and the law of conservation of energy at 41.18%. These findings indicate the need for improvements in teaching methods and the use of more interactive learning media to help students overcome these misconceptions. Regular evaluation and repetition of the material are necessary to ensure better understanding among students. Recommendations that can be made include the use of active learning methods, providing constructive feedback, and increasing the availability of learning resources that students can access outside of school hours. These steps are expected to enhance students' understanding of physics and reduce the level of misconceptions, thereby better preparing them to tackle more complex physics concepts in the future.

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