Jurnal Inovasi Pendidikan

Volume 8, Nomor 12, Tahun 2025
Halaman 203-211

IDENTIFICATION OF MISCONCEPTIONS ON WORK AND ENERGY MATERIAL IN CLASS XI AT SMAN 2 PERCUT SEI TUAN USING THREE TIER DIAGNOSTIC TEST

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Article Info

Article history:
Published Desember 31, 2025

Keywords:
Misconception, Work And Energy, Three Tier Diagnostic Test.

ABSTRACT

Physics concepts such as work and energy are fundamental yet often difficult for students to understand because they require the integration of mathematical representation and conceptual reasoning. Misunderstandings commonly arise when students interpret physical phenomena using everyday intuition rather than scientific principles. This study aims to identify misconceptions held by eleventh-grade students regarding the concepts of work and energy at SMAN 2 Percut Sei Tuan using a three tier diagnostic test. The research employed a quantitative descriptive method involving 32 students as participants. The diagnostic instrument consisted of six items that assessed students' multiple-choice answers, conceptual reasoning, and confidence levels. The findings indicate that misconceptions were the most dominant category, accounting for 53.125% of all responses, followed by conceptual understanding at 25%, lack of understanding at 21.875%, and guessing at 0%. Item-by-item analysis showed that the highest misconception rate occurred in the concepts of free-fall velocity and energy transformation on rough surfaces, each reaching 50%. These results demonstrate that many students still rely on intuitive, everyday reasoning rather than scientific principles. The study concludes that the three-tier test is effective in uncovering students' underlying reasoning errors and can serve as a basis for improving physics instruction.

1. INTRODUCTION

Education is a process that aims to develop students knowledge, skills, and character through guided learning experiences. In the context of modern education, students are not only required to master academic knowledge, but also to possess 21st-century skills such as critical thinking, creativity, collaboration, and communication in order to be able to cope with the rapid development of science and technology (Juita et al., 2024). Schools, as formal institutions, are the main venues for this educational process. In schools, various subjects are taught to broaden students' knowledge, one of which is physics. Physics plays an important role in developing systematic, analytical, and logical thinking, as its concepts are closely related to real phenomena that occur in everyday life (Nugraha & Supradi, 2025).

As a branch of science, physics requires students to be able to understand concepts in depth, not just memorize formulas or mathematical procedures. In fact, many physics concepts are abstract in nature, requiring good representation skills so that students can connect physical phenomena, mathematical models, and conceptual interpretations (Sari, 2021). One subject that requires a strong conceptual understanding is work and energy. Work and energy are concepts in classical physics that study how an object moves and the factors that cause that movement (Jatmika et al., 2021). According to Haji et al. (2023) which states that one of the topics in physics that are considered difficult is work and energy, so students need to improve their mastery of the concepts in this material.

The concepts of work and energy include the definition of work as the product of force and displacement, energy as the ability to do something or work, and various forms of energy that can change from one form to another according to the law of conservation of energy (Niyanti et al., 2022). Giancoli (2005) defines the work done by a constant force on an object as the product of the magnitude of displacement (d) and the component of force parallel (F) to the displacement. A person does work when they apply a force that causes displacement. Although this concept is actually close to everyday life, many students have difficulty understanding it because energy changes are not always immediately apparent, so the physical interpretation of mathematical equations is often not well understood. This is exacerbated when students only focus on applying formulas without understanding the meaning of the concepts behind them (Andayani et al., 2024).

These difficulties often trigger misconceptions. Misconceptions are incorrect understandings that do not correspond to actual scientific concepts but are believed to be true by students (Maison et al., 2020). Misconceptions tend to persist and are difficult to correct because students believe that their understanding is correct and makes sense according to their own logic (Mukminin et al., 2025). In the context of physics learning, misconceptions can arise from various sources, such as everyday experiences, inaccurate explanations from teachers, or inappropriate analogies. Students' difficulties in understanding concepts are not only influenced by the learning process in the classroom, but also by their preconceptions or prior knowledge. Misconceptions can actually be reduced if teachers understand that each student brings preconceptions formed through their own experiences. If the understanding of a concept is based on an initial misconception, then the result of that understanding will differ from the scientific explanations of experts. This kind of understanding may be acceptable in certain conditions, but it does not apply to other situations and cannot be used as a general reference (Ustari et al., 2024).

In the subject of work and energy, misconceptions have been found in previous studies, for example, students assume that work only occurs when objects move fast, energy only exists in moving objects, or that large forces always produce large amounts of work without considering the direction of the force relative to the displacement (Maison et al., 2020). Based on initial observations conducted at SMA Negeri 2 Percut Sei Tuan, some students still showed inaccuracies in explaining the relationship between force and work, misinterpreted the concept of potential energy, and had difficulty understanding energy changes in simple systems. This condition indicates that students' conceptual understanding is still low and needs to be explored further to determine the source of their misconceptions.

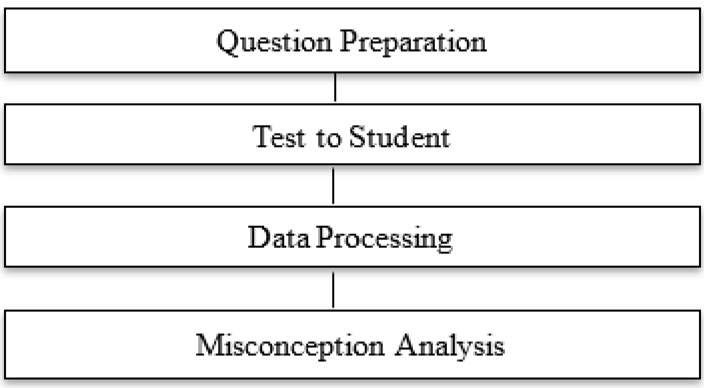
In relation to learning outcomes, students are the main focus in the process of identifying misconceptions. Knowing the types of misconceptions that students have is the first step in determining effective learning strategies. Therefore, a measurement tool is needed that not only assesses answers as “right” or “wrong,” but is also able to reveal the underlying flawed thinking patterns. This is where diagnostic tests play a very important role. Etymologically, the term “diagnostic” refers to the effort to identify a condition based on its symptoms. In the context of education, diagnostic tests serve as instruments to detect specific learning difficulties and misconceptions among students so that teachers can design more targeted learning interventions (Rahmasari et al., 2025).

One widely used instrument for diagnosing students' misconceptions is the three tier diagnostic test. This test is organized into three components, a multiple-choice response, the reasoning that supports the selected answer, and the student's level of confidence in both. By integrating these components, the test provides a clearer profile of students' conceptual understanding, allowing their responses to be categorized into four groups those who truly understand the concept, those who hold misconceptions, those who do not understand, and those who guess. A correct response accompanied by high confidence indicates solid conceptual understanding, whereas an incorrect but confident response reveals the presence of a misconception. Students who answer correctly but express uncertainty are typically guessing, while incorrect answers paired with low confidence reflect a lack of understanding of the concept (Maliada et al., 2022). Based on these characteristics, the three tier test is considered very appropriate and effective for identifying students' misconceptions about work and energy in the 11th grade at SMA Negeri 2 Percut Sei Tuan..

2. METHODELOGY

This study uses a quantitative descriptive approach. The quantitative approach was chosen because it allows for objective measurement and statistical analysis that can provide an accurate picture of the level of students' misconceptions. The research subjects were 32 eleventh-grade students at SMAN 2 Percut Sei Tuan. The research procedure was carried out in several stages, which are summarized in Figure 1 below.

Figure 1. Research Stages



The research instrument used was a three-tier diagnostic test consisting of six questions about the concepts of work and energy. Each question consisted of three levels:

- Level 1: Main questions that test conceptual understanding.
- Level 2: Students reasons for their chosen answers.
- Level 3: Students level of confidence in their chosen answers.

After students complete the test, the data obtained will be analyzed according to the answer key to identify existing misconception patterns. Concept understanding patterns will then be classified into understanding, misconception, not understanding, and guessing. The percentage of misconceptions experienced by students is determined using the following formula:

$$P = \frac{s}{js} \times 100\% \quad (1)$$

(Sari et al., 2024)

Information:

P = Percentage of students in each group (understood concepts, misconceptions, did not understand concepts and guessed).
s = number of students per group category
js = Total number of students participating in the test
Table 1. Categories of Answers in the Three Tier Diagnostic Test

Table 1. Categories of Answers in the Three Tier Diagnostic Test (Wahyudi et al., 2021).

First Tier	Second Tier	Third Tier	Category
Correct	Correct	Confident	Conceptual understanding
Correct	Incorrect	Confident	Misconception
Incorrect	Correct	Confident	Misconception
Incorrect	Incorrect	Confident	Misconception
Correct	Correct	Not confident	Guessing
Correct	Incorrect	Not confident	Lack of understanding
Incorrect	Correct	Not confident	Lack of understanding
Incorrect	Incorrect	Not confident	Lack of understanding

3. RESULT AND DISCUSSION

This section presents a comprehensive description of students' conceptual understanding profiles as analyzed using a three-tier diagnostic test, an instrument that combines multiple-choice responses, conceptual reasoning, and students' confidence levels. This method is highly effective for accurately identifying whether a student's answer reflects conceptual understanding, misconception, or lack of knowledge (Arifuddin et al., 2024).

Distribution of Students' Conceptual Understanding

The distribution in Table 2 shows that misconception is the most dominant category, representing more than half of the student population. This indicates that students' mastery of work and energy concepts is still not optimal, and that incorrect intuitive understandings likely remain deeply embedded. This condition aligns with numerous previous studies reporting that work, energy, and force are among the most misconception-prone topics for high school students (Utami & Rohmi, 2024).

Table 2. Distribution of Conceptual Understanding Based on Overall Categories

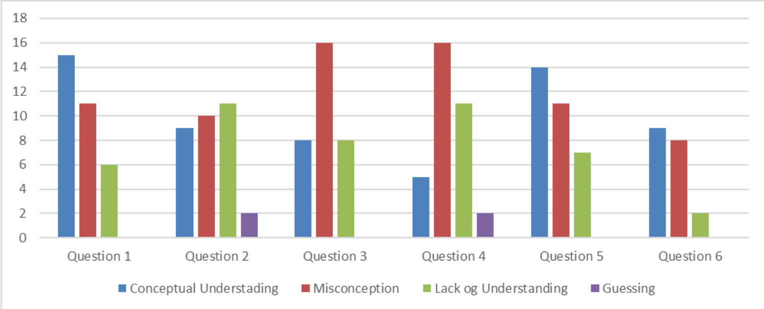
Understanding Category	Number of Students	Percentage (%)	Description
Conceptual Understanding	8	25%	Students provide correct answers, correct scientific reasoning, and high confidence.
Misconception	17	53.125%	Students provide incorrect answers but are confident in their incorrect reasoning, indicating strong belief in erroneous concepts.
Lack of Understanding	7	21.875%	Students do not understand the concept, give random answers, or express uncertainty in their reasoning.

Guessing	0	0%	Students chose answers without meaningful reasoning and with low confidence

Item-by-Item Analysis

To obtain a more comprehensive picture of the students' conceptual patterns, each test item was examined individually through an item-by-item analysis. The distribution of students across the respective diagnostic categories for every item is presented in the following section.

Figure 2. Distribution of students across categories for each item



The percentage distribution of students across categories for each item is presented below.

Table 3. Students Conceptual Understanding per Item Based on the Three Tier Test

Item	Conceptual Understanding (%)	Misconception (%)	Lack of Understanding (%)	Guessing (%)	Brief Concept Description
1	46.875	34.375	18.75	0	Work = force × displacement; force without displacement does not produce work
2	28.125	31.25	34.375	6.25	Work done by friction is negative due to opposing the direction of motion
3	25	50	25	0	Free-fall velocity does not depend on mass
4	15.625	50	34.375	0	Mechanical energy transforms into heat on rough surfaces
5	43.75	34.375	21.875	0	Power = work per unit time
6	28.125	25	46.875	6.25	Identification of work events based on object displacement

Based on the data presented in Table 3, several key patterns regarding students' understanding of work and energy can be identified. Items 3 and 4 exhibit the highest proportion of misconceptions, with 50% of students providing incorrect but confident responses, indicating strongly rooted alternative conceptions. Meanwhile, Item 6 shows the highest percentage of students categorized as lacking understanding (46.875%), suggesting substantial difficulty in recognizing the conditions under which work occurs in real-world contexts. Additionally, guessing responses appear in Items 2 and 6 (each 6.25%), reflecting students' inability to construct meaningful reasoning and signaling conceptual instability, particularly in interpreting the direction of work done by friction and assessing displacement. In contrast, Items 1 and 5 are relatively better understood, with a higher proportion of correct answers, though misconceptions still persist, indicating that students' comprehension is not yet consistently robust. The coexistence of correct answers, misconceptions, and guessing responses demonstrates that conceptual understanding of work and energy is uneven and requires targeted conceptual reinforcement.

General Overview of Students Misconceptions

Overall, the findings indicate that the majority of students do not possess a solid conceptual representation of work and energy. Many students show high confidence in incorrect ideas, which indicates that their misconceptions are persistent and resistant to change. In physics education research, this condition is considered one of the greatest barriers to learning because students are confident that their understanding is correct (Mufti & Sunarti, 2024). Three major patterns of misconceptions emerged:

1. Misconceptions Based on Everyday Intuitive Experiences

Students often rely on non-scientific everyday experiences to explain physical phenomena. Examples include:

a. Feeling tired when pushing a wall same as doing work
   Students equate physical fatigue with mechanical work, who found that "work same as bodily energy expenditure" is a common misconception.
b. Heavier objects fall faster than lighter ones
   This is a classical misconception arising from everyday observations of air resistance affecting lighter objects.

2. Misconceptions Arising from Oversimplified Classroom Explanations

Teachers or textbooks sometimes oversimplify concepts, leading to misunderstanding, such as: energy is lost due to friction. In reality, energy is not lost it transforms into heat. The use of metaphorical language without scientific clarification has been shown to be a significant source of misconceptions.

3. Difficulties Connecting Concepts with Mathematical Representations

In the power item such as item 5, some students fail to understand that power depends on time. This error occurs when students memorize formulas $P = W/(t\ )$ without understanding the underlying concept.

Item-by-Item Discussion

This section presents a more in-depth item-by-item analysis to identify the conceptual roots of students errors. The analysis goes beyond the distribution of responses by examining the reasoning patterns that underlie the emergence of misconceptions. By reviewing each item individually, the primary sources of error can be identified, whether they stem from everyday intuitions, instructional oversimplification, or difficulties linking concepts to mathematical representations. This approach enables a more comprehensive understanding of the cognitive mechanisms that contribute to the formation of students' misconceptions.

1. Work Without Displacement

Students who answered incorrectly commonly believed that work is performed whenever effort or physical fatigue is felt. This shows that students still rely on naïve intuitive reasoning rather than applying the formal definition of work, which requires displacement in the direction of the applied force. This misconception is still prevalent, as many students tend to associate mechanical work with bodily exertion rather than with physical displacement. Such reasoning aligns with what is referred to as phenomenological primitives, in which students rely on personal experience rather than scientific principles.

2. Work Done by Friction

The primary misconception in this category stems from the belief that friction uses up or removes energy, leading students to assume that friction can produce positive or indefinite work. However, friction always acts opposite to the direction of motion, making its work negative by definition. Recent diagnostic studies emphasize that students frequently misunderstand the relationship between friction, energy transformation, and the sign of work, resulting in persistent misconceptions about the nature of frictional forces (Hasrani et al., 2021).

3. Free-Fall Speed and the Role of Mass

The misconception that heavier objects fall faster than lighter ones continues to persist among students, despite being contradicted by fundamental physics principles. Contemporary research indicates that such intuitive reasoning is resistant to conceptual change because students' day-to-day observations often reinforce the idea that mass influences falling speed. This demonstrates that intuitive but incorrect beliefs still strongly shape students' understanding of free-fall motion.

4. Mechanical Energy on Rough Surfaces

Many students assume that energy disappears when objects move across rough surfaces. In reality, mechanical energy is transformed into heat due to friction. Recent research confirms that students commonly perceive energy as a tangible quantity that can be lost or used up, demonstrating a lack of understanding regarding energy conservation and transformation. This misconception remains one of the most persistent in energy related topics.

5. Concept of Power

When responding to power-related problems, students often overlook the role of time and focus solely on the total amount of work performed. This reveals an incomplete understanding of the concept of rate in physics. Recent findings show that students tend to memorize formulas without interpreting their conceptual meaning, resulting in misconceptions about the relationship between work, time, and power (Suswati et al., 2021).

6. Identifying Work Events

The high percentage of students lacking understanding in this item suggests that they experience difficulty distinguishing the relationship between force and displacement in real-world scenarios. Many students believe that merely applying a large force such as holding a heavy object constitutes work, even without displacement.

4. CONCLUSION

The results of this study show that the conceptual understanding of eleventh-grade students regarding work and energy remains low, as reflected in the high misconception rate of 53.125%. These misconceptions arise not only from incorrect conceptual knowledge but also from intuitive reasoning, oversimplified classroom explanations, and difficulties in connecting physics concepts to mathematical representations. Item-level analysis revealed that misconceptions were most prevalent in the concepts of free-fall motion and energy transformation, highlighting these topics as particularly challenging for students. The findings reaffirm that the three-tier diagnostic test is a highly effective tool for distinguishing between true misconceptions, lack of understanding, and guessing.

Therefore, teachers are encouraged to use diagnostic instruments as an initial step in identifying learning difficulties and designing more targeted remedial strategies to enhance students' conceptual understanding.

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