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EXPLORING HIGH SCHOOL STUDENTS' CONCEPT MASTERY OF WORK AND ENERGY TOPICS: A QUANTITATIVE DESCRIPTIVE STUDY WITH INSIGHTS FOR STEM LEARNING

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ABSTRACT

This quantitative descriptive study investigates the concept mastery of work and energy among high school students, specifically focusing on 105 students from the XI MIPA Laboratory UM High School. The research employs a concept mastery test, adapting Bloom's taxonomy indicators from C2 to C6, comprising 15 reasoned multiple-choice questions with a reliability value of 0.704. Student responses, categorized into No Response (NR), No Understanding (NU), Incorrect Understanding (IU), Partial Understanding (PU), and Sound Understanding (SU), reveal a prevalent mastery level in the category of Incorrect Understanding or partial comprehension of misconceptions. Specifically, NR, NU, IU, PU, and SU categories are reported at 4.76%, 39.05%, 52.38%, 3.81%, and 0%, respectively. Subtopics such as work-potential energy and kinetic energy-conservation of mechanical energy law fall within the IU and NU categories. The findings emphasize the need for a tailored learning model addressing misconceptions and aligning scientific explanations with everyday experiences. This study underscores the importance of incorporating learning cycle methodologies, STEM approaches, and formative assessment strategies to enhance students' comprehension of work and energy concepts.

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INTRODUCTION

Physics, as an academic discipline, systematically investigates a diverse array of natural phenomena (Pramesti et al., 2020). The field delineates these phenomena by synthesizing empirical evidence, established principles, and pertinent theoretical frameworks in physics (Lin & Singh, 2013; Rizaldi et al., 2021). Nevertheless, the inherent complexity of physics concepts, characterized by their abstract nature, often poses challenges to comprehension, leading students to develop misconceptions (Santhalia & Yuliati, 2021). This cognitive difficulty arises when students, reliant on personal intuition and logic, formulate ideas that may diverge from established scientific principles, resulting in misunderstandings and conflicts (Mooodley & Gaigher, 2019; Park, 2020). The expeditious resolution of misconceptions among students is imperative, as their persistence can impede the assimilation of subsequent concepts, thereby hindering overall comprehension (Murdoch, 2018).

The comprehension of work and energy, pivotal concepts in physics, remains a formidable challenge for students (Büyükdede & Tanel, 2019; Kurnaz & Arslan, 2014; Pramesti et al., 2020). This scientific domain, which transcends disciplinary boundaries, intricately addresses commonplace scenarios, particularly in the analysis of physical phenomena (Jewett, 2008; Sağlam-Arslan & Kurnaz, 2009). Despite its ubiquity, numerous students encounter difficulties in assimilating the intricacies of work and energy (Dalaklioğlu et al., 2015; Mustofa et al., 2019). Challenges manifest in diverse forms, including the nuanced understanding of the sign or direction of work, encompassing the identification of work as positive, negative, or zero (Barniol & Zavala, 2014; Kim & Pak, 2002). Additional obstacles encompass the intricate association of work with energy conservation within a system (Lindsey et al., 2009) and the adept application of work and energy theorems (Dalaklioğlu et al., 2015; Mustofa et al., 2019). Extensive research consistently indicates the pervasive nature of these difficulties across age groups, spanning from elementary school to university levels (Bécu-Robinault & Tiberghien, 1998; Liu et al., 2002; Maryana & Dwikoranto, 2017).

The challenges associated with mastering the topic of work and energy arise from several factors, including the perception of its abstract nature by students (Chen et al., 2014; Dalaklioğlu et al., 2015), the reliance on numerous mathematical formulas (Dalaklioğlu et al., 2015), and a perceived incongruity between everyday understanding and scientific elucidations of work and energy concepts (Pramesti et al., 2020). Moreover, the manner in which students engage with their environment prior to formal learning significantly influences their perspectives on understanding phenomena. Notably, when confronted with challenges, students tend to draw upon their pre-existing knowledge, even if such knowledge is inaccurate (Docktor & Mestre, 2014).

Hence, it becomes imperative to conduct a thorough investigation into the mastery of the concepts of work and energy. This investigation aims to validate that students possess a comprehensive understanding of the subject matter, enabling them to elucidate phenomena fundamentally based on the principles of work-energy in physics rather than relying solely on the specific nature of the phenomena presented (Kohl & Finkelstein, 2008; Mustofa et al., 2019). Furthermore, this inquiry holds significance as the comprehension of the work-energy theorem forms the foundational basis for the study of mechanics concepts (Mungan, 2005).

The assessment of students' proficiency in the content pertaining to work and energy is crucial from the outset, as it facilitates the tailoring of instructional approaches to enhance conceptual mastery. Consequently, the primary objective of this research is to ascertain the comprehension of concepts encompassed within the domain of work and energy, which includes but is not limited to work, kinetic energy, potential energy, and the law of conservation of mechanical energy, through the implementation of evaluative tests. The anticipated outcome of this study is the acquisition of insights that can inform the development of a pedagogical framework aligned with the distinctive characteristics of the work and energy topic. Specifically, the envisaged learning model is expected to integrate principles from the STEM-based 7E learning cycle and leverage formative assessment strategies, thereby optimizing the educational experience and fostering a more nuanced understanding of the subject matter.

METHOD

This research constitutes a quantitative descriptive study aimed at assessing students' proficiency in concepts related to the work and energy topic. The research sample encompasses 105 students from the XI MIPA Laboratory UM High School. The data collected for this study takes the form of quantitative data derived from students' concept mastery tests on the work and energy topic. The concept mastery test comprises 15 reasoned multiple-choice questions, demonstrating a reliability value of 0.704. Subtopics assessed within the test encompass work, kinetic energy, potential energy, and the law of conservation of mechanical energy. The mastery of concepts is evaluated based on adapted Bloom's taxonomy (Bloom, 2010), encompassing five levels: understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6).

The obtained data from the concept mastery test undergoes descriptive analysis to ascertain the levels and categories of students' proficiency in concepts related to the work and energy topic. Student responses are scrutinized based on concept mastery categories for reasoned multiple-choice questions, as outlined by Saglam-Arslan & Devecioglu (2010). These concept mastery categories are elucidated in Table 1. This analytical approach aims to provide a comprehensive understanding of the students' mastery of concepts, thus informing potential instructional modifications or enhancements to optimize learning outcomes in the work and energy topic.

The categories employed to analyze student responses in the concept mastery test are as follows. (a) No Response (NR), signifying instances where students did not provide any answer or response to the given questions. (b) No Understanding (NU), denoting situations where students exhibited a lack of comprehension or demonstrated an absence of knowledge regarding the concepts assessed. (c) Incorrect Understanding (IU), characterizing responses where students exhibited a misunderstanding or misinterpretation of the concepts, resulting in inaccuracies. (d) Partial Understanding (PU), reflecting responses that indicate a partial grasp of the concepts, suggesting an intermediate level of comprehension that is not fully accurate. (e) Sound Understanding (SU), representing responses that demonstrate a comprehensive and accurate understanding of the concepts assessed in the test.

Table 1. Category level of mastery of concepts for multiple choice reasons questions.

Level	Category	Description	Assessment Criteria
1	No Response (NR)	Not mastering the concept	Students do not choose answers and do not give reasons
2	No Understanding (NU)	Experiencing misconceptions	Students choose the wrong answer and give reasons for answers that are not in accordance with the concept
3	Incorrect Understanding (IU)	Have partial understanding with misconceptions	Students choose the correct answer but the reasons for the answers given are wrong and show misconceptions
4	Partial Understanding (PU)	Have partial understanding	Students choose the correct answer but the reasons for the answers given indicate that only some are understood, there are concepts that are not appropriate in explaining answers
5	Sound Understanding (SU)	Have a complete understanding	Students choose the correct answer, give reasons for the answers according to the concept, and can meet the indicators of mastery of the concept

Table 2. Level of mastery of student concepts in work and energy.

Level	Percentage	The Number of Students
No Response (NR)	4.76%	5
No Understanding (NU)	39.05%	41
Incorrect Understanding (IU)	52.38%	55
Partial Understanding (PU)	3.81%	4
Sound Understanding (SU)	0.00%	0

RESULTS

The data derived from students' responses to the concept mastery test in the topic of work and energy were subjected to meticulous analysis utilizing a previously established assessment rubric. Each student response was meticulously scored and subsequently classified in accordance with predetermined levels of conceptual mastery. Upon an assessment of student scores, the computed average conceptual mastery score was determined to be 23.48 out of a possible 60. The ensuing tabulation delineates the percentage distribution of students across distinct levels of overall conceptual mastery, as explicated in Table 2.

As delineated in Table 2, the evaluation of students' conceptual mastery indicates a prevailing trend within the spectrum extending from NR to PU. Specifically, a notable portion of the student cohort exhibits a level of proficiency categorized as follows: NR constituting 4.76%, NU encompassing 39.05%, IU comprising 52.38%, PU representing 3.81%, and SU representing 0.00%. This distribution underscores the current status of students' comprehension levels within the ambit of the work and energy topic, revealing a preponderance of responses falling within the lower tiers of conceptual mastery.

Mastery of Student Concepts Based on the Indicators of Each Item

The administered proficiency assessment on the principles of work and energy comprised 15 items in the form of multiple-choice questions. The score distribution and students' conceptual mastery levels for each item are illustrated in Figure 1. The figure delineates the distribution of student scores for the 15 questions constituting the work and energy concept mastery test. Notably, a predominant number of students exhibited a NR level in questions 7, 9, 10, 11, 12, 13, 14, and 15, signifying an absence of answers or justifications. Question 14 garnered the highest count of 77 students at the NR level. Conversely, questions 1, 2, and 6 predominantly saw students at the NU level, where responses reflected erroneous conceptual understanding. Question 1 had the highest count of 55 students at the NU level. In contrast, questions 3, 4, 5, and 8 primarily exhibited a SU level, indicating correct responses and justifications aligned with the conceptual framework. Questions 3 and 4 boasted the highest count of 52 students at the SU level. The tabulated outcomes, organized based on the average student scores for each item, are presented in Table 3.

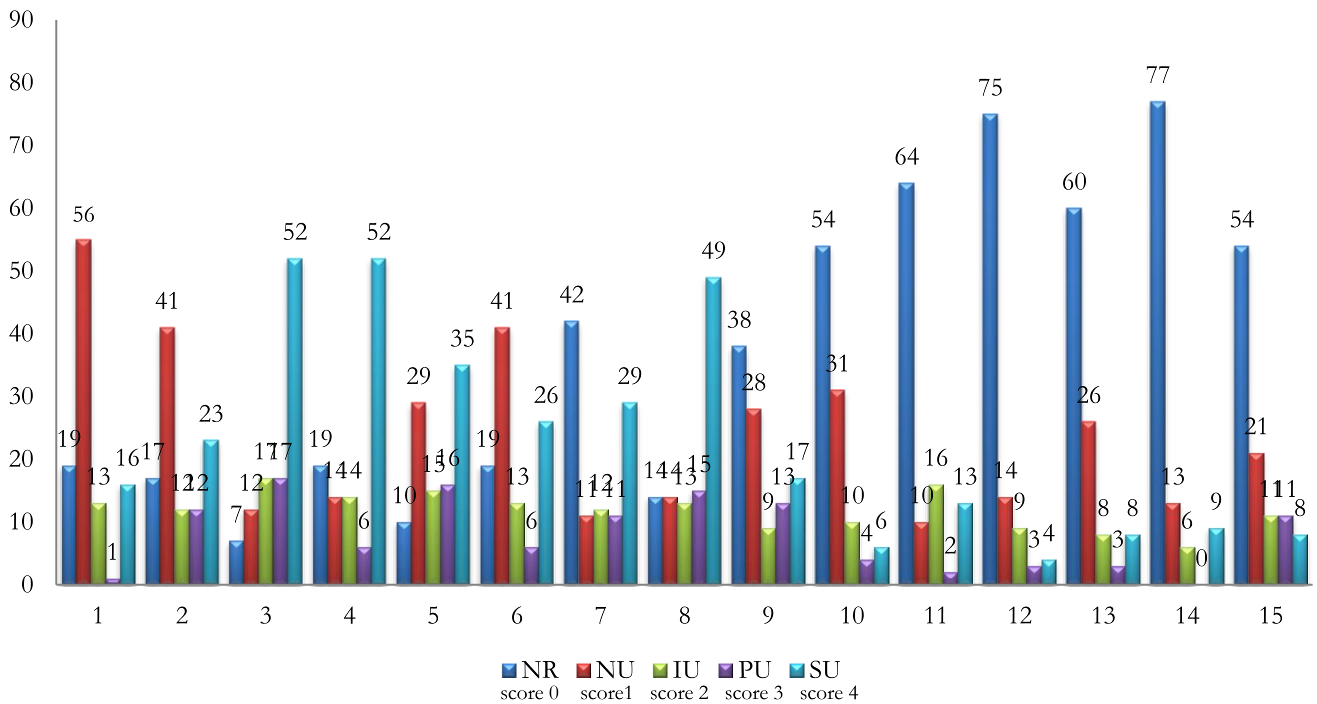

Figure 1. Distribution of students' concept mastery category based on the indicators of each item.

Table 3. Results of students' concept mastery category.

Number of Item	Indicator	Average Score	Average Score Rounding	Category
1	C4	1.42	1	No Understanding
2	C3	1.84	2	Incorrect Understanding
3	C4	2.90	3	Partial Understanding
4	C5	2.55	3	Partial Understanding
5	C2	2.35	2	Incorrect Understanding
6	C4	1.80	2	Incorrect Understanding
7	C5	1.75	2	Incorrect Understanding
8	C4	2.68	3	Partial Understanding
9	C6	1.46	1	No Understanding
10	C4	0.83	1	No Understanding
11	C3	0.95	1	No Understanding
12	C5	0.54	1	No Understanding
13	C4	0.79	1	No Understanding
14	C3	0.58	1	No Understanding
15	C4	1.03	1	No Understanding
Average		**1.57**	**2**	**Incorrect Understanding**

The outcomes of the conceptual mastery categorization in the toppic of work and energy reveal a prevailing trend wherein the average student proficiency is situated predominantly at the level of Incorrect Understanding (IU). This is corroborated by instances where students successfully select the correct answers, yet their provided justifications are erroneous or reflect misconceptions. Among the 15 questions posed, the students' responses manifest in four questions falling under the category of IU, three questions demonstrating PU, and eight questions indicative of NU. These findings collectively underscore a suboptimal grasp of the work and energy concepts among the student cohort. Despite the occasional attainment of the SU level by certain students for specific items, the overarching pattern suggests that, on average, students possess only a partial understanding of the subject matter, marked by persistent misconceptions.

Mastery of Student Concepts Based on Indicators of Each Subtopic

The examination assessing proficiency in the comprehension of the work and energy concept encompasses subtopics including work, potential energy, kinetic energy, and the law of conservation of mechanical energy. The allocation of questions across these subtopics is as follows: four questions pertain to work, five to potential energy, four to kinetic energy, and two to the conservation of mechanical energy. Figure 2 presents an elucidation of the distribution of students' categorization based on concept mastery for each subtopic.

Figure 2 delineates the distribution of student response scores for each subtopic. Within the realm of work and potential energy, a preponderance of students has attained the SU level, with 35 students for work and 31 students for potential energy. At this proficiency tier, students demonstrate the capability to furnish accurate responses and articulate justifications aligned with the pertinent conceptual framework. In the topics of kinetic energy and the law of conservation of mechanical energy, conversely, the majority of students manifest a NR level, comprising 63 students for kinetic energy and 66 students for the law of conservation of mechanical energy. At this level, students abstain from selecting answers and providing rationales. The outcomes of the categorization, organized on the basis of the mean student score for each subtopic, are presented in Table 4.

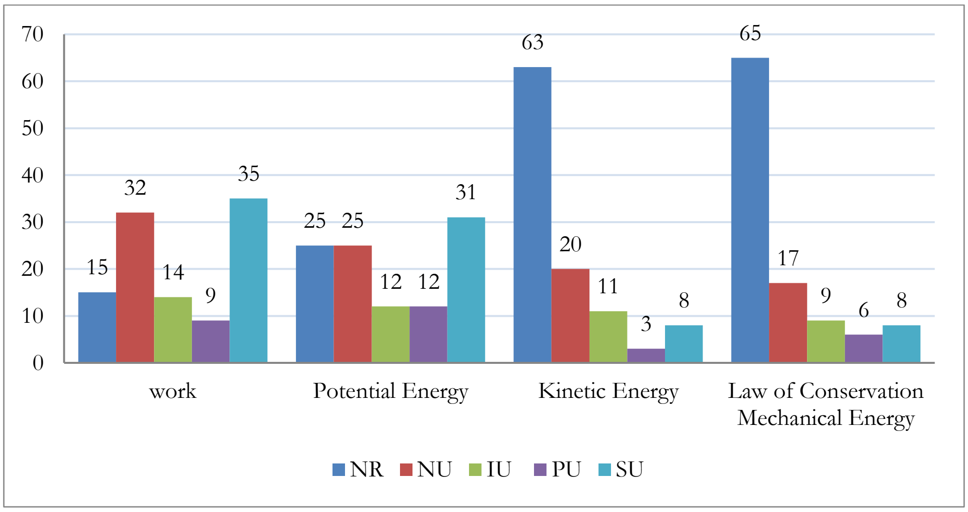

Figure 2. Distribution of students' concept mastery categories based on each subtopic.

Table 4. Results category mastery of student concepts each subtopic.

No	Subtopic	Average Score	Average Score Rounding	Category
1	Work	2.18	2	Incorrect Understanding
2	Potential Energy	2.01	2	Incorrect Understanding
3	Kinetic Energy	0.78	1	No Understanding
4	Law of Conservation of Mechanical Energy	0.80	1	No Understanding

The outcomes derived from the categorization of conceptual mastery within the subtopics of work and energy reveal a pronounced deficiency in students' command of these concepts, notably evident at the NU level for the subtopics of kinetic energy and the law of conservation of mechanical energy. This deficiency is underscored by students' responses, where even those capable of selecting answers tend to provide incorrect justifications pertaining to these specific subtopics. Concurrently, the subtopic of work and potential energy demonstrates a prevalence of students falling within the category of IU. This collectively signifies that students encounter challenges in achieving a robust conceptual mastery, leading to misunderstandings or misconceptions within specific subtopics.

DISCUSSION

The outcomes of the data analysis revealed that students at XI MIPA Laboratory UM High School exhibited a state of partial conceptual mastery with prevalent misconceptions, as documented by Saglam-Arslan and Devecioglu (2010). In aggregate, the overall proficiency level in students' conceptual grasp aligns with an overarching characterization of "Incorrect Understanding". This concurrence finds support in parallel research endeavors focused on the topic of work and energy, indicating its classification as a challenging topic for students within this age cohort, particularly at the high school level (Bécu-Robinault & Tiberghien, 1998; Büyükdede & Tanel, 2019; Maryana & Dwikoranto, 2017; Kurnaz & Arslan, 2014; Liu et al., 2002; Pramesti et al., 2020). Within the confines of the "Incorrect Understanding" category, students demonstrate the capability to select correct answers, yet their provided justifications are erroneous, thereby underscoring the prevalence of misconceptions within this cohort.

Mastery of Student Concepts by Category

Students positioned at the NU level or grappling with misconceptions are notably prevalent in question number 1, encompassing a cohort of 56 students. Question number 1 is indicative of an analytical task focused on the physics concept of work (C4). The scenario involves a child pulling a trolley, prompting students to ascertain the work performed by the gravitational force acting on the trolley. While many students demonstrate familiarity with work concepts through formulas such as $W = F \times s$ or recognizing displacement on the pushed trolley, a common challenge arises in comprehending the gravitational force stipulated in the problem. Students encounter difficulty in identifying the forces at play within an object, leading to errors in determining the direction of force vectors, notably the weight force (w) and pushing force vectors (F) on the object system.

This pattern aligns with prior research highlighting students' struggles in understanding the sign or direction of work in response to a given force, resulting in errors when categorizing work as positive, negative, or zero (Barniol & Zavala, 2014; Kim & Pak, 2002). This underscores the notion that challenges in mastering physics concepts in specific areas can impede comprehension of more intricate topics. The identified difficulties are consistent with existing research indicating that misconceptions in particular subjects may hinder students' proficiency in grasping other interconnected concepts (Murdoch, 2018). A detailed presentation of the questions and answers associated with student number 1 is available in Figure 3.

Students exhibiting partial understanding with misconceptions, corresponding to the IU level, are notably prevalent in question number 5. This problem, marked by an indicator elucidating the factors influencing work through potential energy (C2), involves a scenario wherein an individual moves a suitcase. Students are tasked with determining the factors impacting work by the force of gravity. A noteworthy challenge arises as some students encounter difficulty identifying the factors influencing work based on the theorem of work and potential energy. According to this conceptual framework, work by gravity is influenced by mass (m), gravity acceleration (g), and the change in position or difference in height of the object before and after movement (Δh).

A child pulls a trolley on a flat plane so that the trolley is transferred. The work made by the weight of the trolley is …

a. Not the same as zero
b. Same as zero
c. In the direction of the displacement direction
d. In the direction of the earth's gravitational force

Reason: …………………………………………….

(a)

C. In the direction of the displacement direction

Reason: $w = F . s$. Distance influenced by direction. Work is influenced by force and distance. The existence of a work is marked by the displacement

(b)

Figure 3. (a) Question number 1 and (b) students's answer for question number 1.

Arin moved the suitcase from the floor to the table. In addition to the weight of the suitcase, what factors determine the work made by the earth's gravitational force to the suitcase are shown as follows:

1) How to lift a suitcase from the floor to the table vertically or through another longer path
2) The position of the suitcase when lifted, namely vertically (standing upright) or horizontal
3) The height of the table from the surface of the floor

Which statement is true?

a. (1) only
b. (2) only
c. (3) only
d. (1) and (2)
e. (2) and (3)

Reason: ………………………………………….

(a)

E. (2) and (3)

Reason: Because when the suitcase is lifted in a horizontal position and with a fairly high one it will require greater work

(b)

Figure 4. (a) Question number 5 and (b) students's answer for question number 5.

Consider the following activities:

1. Runner athletes surround the field 2 times and return to the starting point
2. Andi pushed the table so that the table moved as far as 2 meters
3. The earth surrounds the sun for one year
4. The parachutist keeps away from a height of 800 meters

From the above activities, which work is not zero?

a. 1 and 2
b. 1 and 3
c. 2 and 4
d. 1, 2, 3, and 4

Reason: ………………………………………….

(a)

C. (2) and (4)

Reason: Because if an object experiences a displacement and the starting point returns to that point again then the displacement $s = 0$, so that the work is also $W = 0$

(b)

Figure 5. (a) Question number 3 and (b) students's answer for question number 3.

However, a subset of students erroneously associates the position of the suitcase, whether lifted vertically or horizontally, as a factor influencing work. This aligns with prior studies underscoring students' challenges in applying the concepts of work and energy theorems (Dalaklioğlu et al., 2015; Mustofa et al., 2019). Moreover, students have yet to provide a fundamental explanation of phenomena based on work-energy principles in physics, relying instead on experiential understanding derived from their interactions with the environment (Kohl & Finkelstein, 2008; Mustofa et al., 2019). This observation substantiates the notion that when students conceptualize ideas based on intuition and logic, they often encounter misunderstandings or conflicts with scientific concepts (Mooodley & Gaigher, 2019; Park, 2020). The particulars of item number 5 and corresponding student responses are elucidated in Figure 4. Students characterized by a partial understanding of the concept, specifically at the PU level, are predominantly associated with question number 3. Notably, 17 students managed to select the correct answer, albeit their provided rationales indicate that only a subset comprehended the underlying concepts. The explanations put forth by students still exhibit inappropriate conceptualization. In the context of problem number 3, students are tasked with analyzing the physics concept of work (C4). The problem encompasses various phenomena, prompting students to scrutinize activities involving work. Students generally grasp ($W = F \cos \theta \cdot s$) as the concept of work, acknowledging that if there is displacement ($s \neq 0$), the force induces object movement, thereby precluding a work value of zero. Nevertheless, a contingent of students encounters challenges in furnishing comprehensive explanations aligned with the complete concept of work. Instead, they rely on a constrained vocabulary and understanding, culminating in less nuanced responses. Detailed insights into item number 3, alongside corresponding student responses, are presented in Figure 5.

Mastery of Student Concepts Based on Indicators of Each Subtopic

The tabulated data in Table 3 indicates that the subtopic with the highest average score in concept mastery is related to the "work" category. However, despite the capacity of some students to attain the SU level within this subtopic, the overall average student proficiency rests at the IU level. This underscores a prevalent inadequacy in the mastery of concepts among the majority of students. Specifically, within the "work" subtopic, students frequently exhibit partial understanding accompanied by misconceptions.

Students generally acknowledge the concept of work as a consequence of a force acting on an object, causing the object to move over a certain displacement. Moreover, students are capable of discerning instances where the work concept yields a zero value in the absence of displacement. Nevertheless, challenges emerge in the identification of force vectors' directions, such as weight force (w) and push or pull force vector (F), within an object system. Consequently, students encounter difficulties in determining the sign or direction of work in response to a given force, leading to errors when categorizing work as positive, negative, or zero—a phenomenon noted in prior studies (Barniol & Zavala, 2014; Kim & Pak, 2002).

The analysis of concept mastery reveals that the subtopic with the second-highest average score pertains to "potential energy". Within this subtopic, the average student proficiency is situated at the IU level, with an average score of 2.01, indicating a prevailing deficit in conceptual mastery among the majority of students. Within the realm of potential energy, students often grapple with partial understanding accompanied by misconceptions. While students generally grasp the meaning of potential energy as the energy inherent in an object due to its position within a specific reference field, challenges persist in applying the concepts of work and potential energy theorems.

A notable difficulty arises as students tend to attribute the quantity of work to factors beyond those stipulated by the mass (m), gravitational acceleration (g), and the change in position or difference in height of the object before and after movement (Δh). This observation aligns with the broader trend where students encounter challenges in providing fundamental explanations of phenomena based on work-energy principles in physics (Docktor & Mestre, 2014). Instead, their responses are often grounded in experiential understanding derived from interactions with the environment, reflecting a reliance on intuition and logic rather than a comprehensive grasp of scientific concepts.

The examination of concept mastery reveals a notably low average score within the subtopic of "kinetic energy". Within this domain, the average student proficiency stands at the NU level, marked by an average score of 0.78. This underscores a pervasive deficit in conceptual mastery among the majority of students, with numerous misconceptions prevalent in this subtopic. While students generally comprehend the meaning of kinetic energy as the energy possessed by an object due to its speed, challenges emerge in analyzing the relationship between theorem concepts of work and kinetic energy ($W = \Delta E_k$) or ($F \cdot s = \Delta E_k$).

Students encounter difficulties when presented with scenarios involving two objects of different masses pushed with the same force over the same distance. In accordance with the theorem of work and kinetic energy, both objects should exhibit the same energy. However, students often overlook information regarding force vector (F) and displacement (s) on objects, erroneously asserting that the quantity of kinetic energy is influenced by mass (m). Additionally, some students incorrectly associate larger masses with greater kinetic energy based on the kinetic energy formula ($E_k = \frac{1}{2}\, m \cdot v^2$). This pattern indicates a tendency among students to explain physical phenomena not in alignment with the principles and concepts of physics, but rather relying on formulaic interpretations. This inclination contributes to the perceived difficulty of the work and energy topic due to the prevalence of mathematical formulas (Dalaklioğlu et al., 2015). Moreover, students grapple with challenges in associating work with energy conservation in a system (Lindsey et al., 2009), as well as applying the concepts of work and energy theorems (Dalaklioğlu et al., 2015; Mustofa et al., 2019).

The evaluation of concept mastery within the subtopic of the law of the conservation of mechanical energy reveals a notably low average score. Within this subtopic, the average student proficiency stands at the NU level, denoted by an average score of 0.80. This signifies a prevalent deficiency in conceptual mastery among the majority of students, accompanied by numerous misconceptions. While some students manage to select correct answers in alignment with the concept of the law of conservation of mechanical energy, they often fail to provide appropriate reasons or offer no reasoning at all.

A significant aspect of students' challenges in this subtopic lies in their inability to recognize and apply the law of conservation of mechanical energy to systems unaffected by external forces (C3). Moreover, they struggle with the analysis of graphs related to mechanical energy in systems devoid of external force influence (C4). This aligns with prior research indicating persistent difficulties among students in grasping abstract concepts such as energy (Chen et al., 2014; Dalaklioğlu et al., 2015). Additionally, students confront challenges in expressing concepts or statements through mathematical language, graphs, diagrams, and other representational forms. This multifaceted difficulty contributes to the overall low mastery of concepts within the law of the conservation of mechanical energy subtopic.

CONCLUSION

This study underscores the prevailing low mastery of concepts among students in the work and energy topic, primarily categorized under the domain of "Incorrect Understanding". A detailed breakdown of student proficiency across the NR, NU, IU, PU, and SU categories reveals percentages of 4.76%, 39.05%, 52.38%, 3.81%, and 0%, respectively. The subtopics of work-potential energy, kinetic energy, and the law conservation of mechanical energy all exhibit categorizations within the IU and NU categories. In the work subtopic, students encounter challenges in determining the sign or direction of work against a given force, resulting in errors when assigning positive, negative, or zero values to work. The potential energy subtopic highlights difficulties in identifying factors influencing work based on the concepts of work and potential energy theorems. Furthermore, students struggle to offer explanations grounded in fundamental physics principles, relying instead on experiential understanding derived from interactions with the environment. The kinetic energy subtopic reveals prevalent misconceptions among students, particularly in their inability to analyze the relationship between the concepts of work and the kinetic energy theorem. Within the law conservation of mechanical energy subtopic, students grapple with challenges in applying the law and expressing concepts or sentences through mathematical language, graphs, diagrams, and other forms of representation. The study underscores the complexity of work and energy concepts for students, attributing their difficulties to the misalignment between everyday experiences and scientific explanations. Consequently, a learning model tailored to the characteristics of work and energy is essential. This model should aim to rectify preconceptions and misconceptions while integrating real-world problems into the learning process (Olaoluwa & Olufunke, 2015). The study's outcomes are anticipated to inform the design of a STEM-based 7E learning cycle model and the development of formative assessment strategies.

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AUTHOR CONTRIBUTIONS

MKP was involved in to investigate the research, conducting analysis, and wrote the manuscript. P was involved in conceptualizing the study, managing project administration, and supervised the findings of this work. NM was involved in reviewing the test and supervised the findings of this work. MA was contributed in reviewing the manuscript. All authors discussed the results and contributed to the final manuscript.

CONFLICT OF INTEREST STATEMENT

Regarding the research, writing, and publication of this paper, the authors state they have no competing interests.

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