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Learning Interest and Gender Differences in Indonesian High Schools: Their Influence on Understanding the Concepts of Work and Energy

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Abstract: This study examines the influence of gender and learning interest (cognitive [CI] and emotional [EI]) on high school students' conceptual understanding of Work and Energy in physics. A quantitative correlation design was employed with 64 students. A 21-item conceptual test and a 16-item Likert-scale interest questionnaire (7 CI, 9 EI) were administered. Data were analyzed using descriptive statistics, Mann-Whitney U test (gender), and Spearman correlation (interest). Only 28% of students fully understood the concepts, while 42% did not. No gender differences were found, but interest significantly correlated with conceptual understanding (*r* = 0.36, *p* < 0.05). Conclusion: Interest, not gender, predicts conceptual understanding in physics. The study uniquely integrates cognitive and emotional interest dimensions while assessing gender effects. Physics instruction should enhance interest through real-life contexts to improve engagement and learning. Provides empirical evidence that fostering student interest is crucial for conceptual mastery in physics.

Keywords: Gender Differences, Learning Interest, Work and Energy

A. Introduction

Understanding concepts in physics has a very important role, especially because physics as an applied science is always related to natural phenomena that can be observed in everyday life and in the surrounding environment (Fitriani et al., 2023). Understanding physics concepts helps students connect the knowledge they already have, making it easier to understand the topic, and reinforcing the relationship between the concepts learned (Tong et al., 2023; Triani et al., 2025). A strong understanding of physics is one of main foundations in encouraging the development of science and technology (Triani et al., 2025). However, students often hold misconceptions, which refer to ideas that are believed to be correct but do not align with scientific understanding, or they may misapply correct concepts in inappropriate contexts (Hammer, 1996). Conceptual understanding in these domains is often hindered by students' misconceptions, abstract reasoning challenges, and lack of contextual application (Mustofa et al., 2019). Therefore, it is important to analyze students’ conceptual understanding to recognize the different forms of prior knowledge that students have.

Among the core topics in physics, energy is a key concept in many fields of science (Park & Liu, 2021), and one of the important goals in science education is to help all students understand the concept of energy thoroughly (Kubsch, 2024). Misunderstandings about energy are prevalent, and these misconceptions can hinder students' learning in both physics and broader scientific contexts (Shrestha et al., 2023). This problem is particularly significant as it can affect students' long-term engagement and proficiency in science (Wijekumar et al., 2024; Ganesan & Morales, 2024). Furthermore, misunderstanding of energy can hinder their understanding of related topics, such as thermodynamics, mechanics, and even environmental science (Park & Liu, 2021). By analyzing students’ understanding of energy, educators can develop better pedagogical strategies to address these challenges, which can lead to enhanced learning outcomes.

Previous research has focused on diagnosing and addressing misconceptions in energy concepts, using a variety of instruments such as the Energy Concept Assessment (ECA) (Kubsch, 2024; Kellberg et al., 2024). Recent advances have incorporated isomorphic testing, a method involving equivalent forms of a test that assesses the same underlying concepts in different ways to create a more refined assessment tool (Kusairi et al., 2022; Maison et al., 2023). This study builds on these advancements by adapting isomorphic tests from the ECA, aiming to offer a more accurate representation of student understanding. The adaptation of isomorphic tests represents an innovative method for assessing conceptual understanding, which may offer more reliable and valid results in evaluating student comprehension. The current study expands on earlier work by applying a refined approach to the same core issue.

In addition to cognitive challenges, motivational factors also influence students’ learning outcomes in physics. Contemporary physics education research is moving toward a more integrated understanding of learning by incorporating cognitive, affective, and demographic factors (Hauspie et al., 2023; Kökver et al., 2024). Student interest, which consists of cognitive interest (CI) and emotional interest (EI), has been recognized as a motivational factor influencing student engagement and achievement in science education (Mazer, 2012; Ramadhany et al., 2024). Cognitive interest is interest based on cognitive understanding (such as the ability to understand, remember, and recall material), while emotional interest is affective engagement demonstrated through enthusiasm and enjoyment during learning (Mazer, 2012; Tang et al., 2022). Although several studies have examined the role of interest in learning, few have explored the distinct contributions of its cognitive and emotional dimensions to conceptual understanding in the topic of Work and Energy. In addition, although gender differences in science achievement have been investigated (Nieminen et al., 2013; Kusumaningsih et al., 2019), the combined effect of gender and interest on conceptual understanding has not been fully examined in the context of high school physics, particularly in the topic of Work and Energy.

While various studies have explored misconceptions and the effectiveness of isomorphic assessments in physics, the combined impact of cognitive and emotional interest (CI and EI) on students' conceptual understanding remains underexplored especially within the topic of Work and Energy at the high school level. Based on the issues outlined above, this study aims to investigate how the different dimensions of student learning interest, cognitive interest and emotional interest, and gender are related to students' conceptual understanding of the physics topic Work and Energy. This study is novel in its dual focus on (1) the effects of cognitive and emotional interest on students' understanding of Work and Energy, and (2) the role of gender as a possible moderate or differentiating factor. By employing categorized indicators of conceptual understanding and analyzing their relationship with both interest types and gender, the study provides a more nuanced picture of how students learn physics. Therefore, the central research question addressed in this study is: To what extent do gender, cognitive interest, and emotional interest influence high school students' understanding of the concepts of Work and Energy?

B. Methods

The method used in this research is a quantitative correlational design to investigate the influence of learning interest and gender on students' conceptual understanding of Work and Energy. This research was conducted at a state high school in Bojonegoro, Indonesia, during the second semester of the 2024/2025 academic year. The respondents consisted of 64 11th-grade students and selected using a purposive sampling technique with the following criteria 1) Students completed instruction on the topic of Work and Energy in the physics curriculum; 2) Students consented to participate in the study; 3) Students were available and present during the data collection period.

The sample included both male and female students, allowing for gender-based comparisons. To collect the data, two instruments were used: Conceptual Understanding Test: This test consisted of 21 multiple-choice questions related to Work and Energy, designed based on a three-tier structure aligned with defined indicators see

Table **1**. The items are randomized to prevent pattern recognition or memorization. Each group of three questions represented one conceptual indicator, allowing classification of students into three conceptual understanding levels: understands (score 2), moderate (score 1), and does not understand (score 0) (Kusairi, 2020) see **Error! Reference source not found.**. The reliability of the instrument is based on a Cronbach's alpha value of 0.86.

The Student Interest Scale (SIS) instrument used was developed by Mazer, (2012). This instrument measured two dimensions of learning interest, Cognitive Interest (CI), assessed through 7 Likert-scale items and Emotional Interest (EI), assessed through 9 Likert-scale items. The Likert-scale ranged from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was adapted from validated interest scales and modified to fit the physics context. Reliability testing of the scale demonstrated excellent internal consistency, with a Cronbach's alpha of 0.91 for Cognitive Interest (CI), 0.97 for Emotional Interest (EI), and 0.96 for the overall Student Interest Scale (SIS).

Table 1. Mapping of conceptual indicators, contexts, and number of questions

Concept	Context	Questions
Work	Applying the concept of work by forces acting on an object moving at constant speed and understanding that the total system work can be zero even if there are forces acting.	2, 12, 15
	Analyzing the work done by a force on an object based on the magnitude of the force, displacement, and the angle between the force and the direction of displacement.	3, 6, 19
Work and Energy Theorem	Applying the concept of kinetic energy in a system consisting of two objects, by considering that kinetic energy is a scalar quantity that is summed without regard to direction.	1, 9, 16
	Analyzing the relationship between work, force, kinetic energy, and energy change of an object in a system without friction.	8, 14, 21
	Analyzing changes in potential energy (gravitational or spring) based on physical system characteristics, changes in position, and related parameters (such as mass, spring constant, or displacement).	5, 10, 17
Mechanical Energy Theorem	Analyzing the change and conservation of mechanical energy (potential and kinetic energy) in various physical systems.	4, 13, 20
	Analyzing of kinetic energy changes due to work done by forces (both conservative and non-conservative) under various path conditions.	7, 11, 18

The data analysis was conducted in several steps using IBM SPSS Statistics v27. Descriptive statistics were used to summarize conceptual understanding levels, interest scores, and gender distribution. Conceptual understanding scores were categorized by indicator and transformed into conceptual understanding levels. A normality test using Kolmogorov-Smirnov was conducted to determine the appropriate statistical tests. A normality test using Kolmogorov-Smirnov was conducted to determine the appropriate statistical tests. Since the data were not normally distributed, to examine gender-based differences in conceptual understanding we analyze data using Mann-Whitney U Test. Also, to assess the relationship between student interest (CI, EI, and combined interest) and conceptual understanding we analyze data using Spearman correlation. To examine whether gender moderates the relationship between student interest and conceptual understanding, a moderated linear regression analysis was conducted. The analysis treated student interest (combined cognitive and emotional interest) as the predictor, conceptual understanding as the outcome variable, and gender as the moderator. To address multicollinearity, the student interest variable was mean centered before creating the interaction term. All analyses were conducted with a significance level of 0.05.

Table 2. Level of students' conceptual understanding

Number of Correct Answers (out of 3)	Score	Level of Understanding	Description
3 correct answers	2	**Understand**	Students demonstrate full conceptual understanding and can apply the concept consistently in different contexts.
2 correct answers	1	**Moderate Understand**	Students have partial understanding but may still have confusion in one context.
0–1 correct answer	0	**Not Understand**	Students show no or minimal understanding; likely misconceptions are present, or answers are guessed.

Source: (Kusairi, 2020)

C. Results and Discussion

The findings of this study reveal a concerning trend in students' conceptual understanding of the physics topic Work and Energy. Out of the total respondents, only 28% demonstrated understanding of the concepts, while 30% fell into the moderate category, and the largest group, 42%, showed a lack of conceptual understanding see Figure 1. This indicates that a significant portion of students struggle to construct and apply correct conceptual models related to work, energy, and their interrelationships in physical contexts. Such results align with existing literature that highlights the persistent difficulty students face in grasping abstract physics concepts. For example, (Tong et al., 2023) explain that many students enter physics classes with intuitive but incorrect understandings, particularly when dealing with energy transfer and transformation. Singh & Rosengrant, (2003) similarly reported that even well-performing students often fail to apply the work-energy theorem consistently across different problem scenarios. When students memorize without understanding, they cannot effectively adapt their knowledge to unfamiliar problems (DeDecker et al., 2022). Students to struggle with applying concepts in varied situations and to rely on superficial problem-solving approaches can be directly attributed to an overemphasis on algorithmic problem-solving in physics classrooms (Docktor & Mestre, 2014). This approach may inadvertently hinder the development of robust, transferable conceptual frameworks, leading students to depend on pattern matching and memorized equations rather than fostering a deeper, more adaptable understanding necessary for deeper conceptual understanding (Bao & Fritchman, 2021).

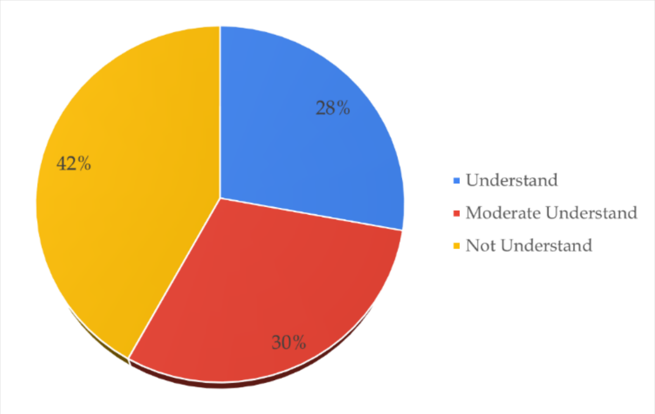

Figure 1. Distribution of Conceptual Understanding Levels

The variation in correct response rates across the 21 items highlights specific conceptual areas where students struggle. For example, several items show a correct response rate below 50%, suggesting that those questions involve concepts that are either misunderstood or require higher-order thinking skills see Figure 2. These findings support earlier work by Mcdermott, (1997) and Aviani et al., (2015), who emphasized that conceptual questions requiring transfer and synthesis are particularly challenging for students, especially when these are presented in unfamiliar or decontextualized forms. Meanwhile, questions with a response rate above 70% may indicate more familiar or straightforward concepts. This variability can inform educators about which indicators need reinforcement and help identify potential misconceptions in students' conceptual frameworks.

Moreover, such uneven patterns may also reflect inconsistencies in students' abilities to transfer knowledge across different contexts. Although they may recognize a concept in a familiar problem, they often fail to apply it when presented in a new or abstract situation (Aviani et al., 2015). This is consistent with findings from physics education research, such as those by Mcdermott, (1997), who found that students frequently perform well on algorithmic tasks but struggle with conceptual interpretation. In the context of Work and Energy, students may memorize the formulas without truly grasping when and how to use them meaningfully (Singh & Rosengrant, 2011; Docktor & Mestre, 2014; Tong et al., 2023). Similar to DeDecker et al., (2022) statement that students memorize without understanding, this limits their ability to apply their knowledge effectively to new problems. Another possible explanation for the low response rates in certain items is related to cognitive load and question design. Questions requiring multi-step reasoning or the integration of several principles (such as combining the work-energy theorem with energy conservation) tend to have lower response rates, as they demand not only understanding but also strategic thinking. On the other hand, items involving isolated facts or one-step calculations tend to yield higher scores, even if the student lacks deep understanding (Tong et al., 2023).

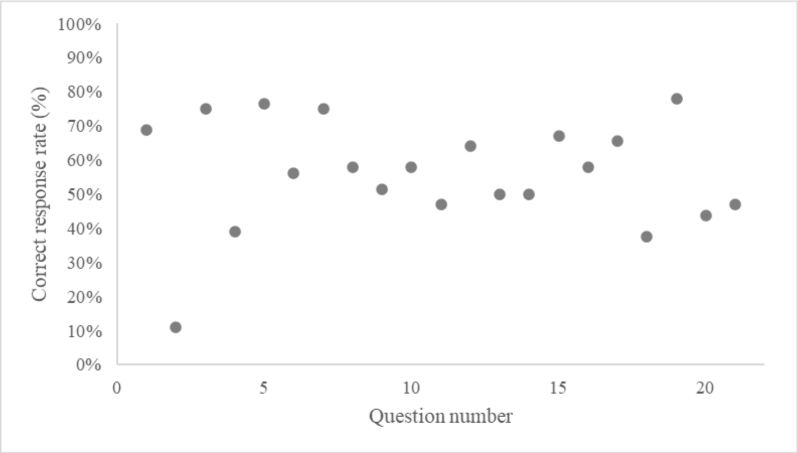

Figure 2. Item-Level Correct Responses for Work and Energy

Contextual sensitivity in performance was also evident. In the Work concept, Context A, which involves understanding that net work can be zero despite the presence of forces, yielded low understanding levels among both genders, see

Table **3**. This reflects the abstract nature of the concept, which may not be intuitively grasped without strong conceptual grounding. Students tend to think that if there is work as a result of force, then net work cannot be zero, ignoring the possibility that the forces acting may cancel each other out or that displacement does not occur in the direction of the force. In contrast, Context B, which involved numerical and geometric reasoning (force magnitude, displacement, and angle), showed much higher understanding, suggesting that concrete computational contexts may be more accessible for learners. This pattern aligns with findings by Distrik et al., (2021) and Munfaridah et al., (2021), suggesting that concrete representations can scaffold student understanding more effectively than abstract formulations. For the Work and Energy Theorem, female students had a better understanding of Context C questions than Context B questions. This again demonstrates the sensitivity of context in conceptual understanding, where students may perform differently depending on how familiar or realistic a scenario seems (Mustofa et al., 2019). In the case of Mechanical Energy Theorem, the Context A items, which involved interpreting potential energy in spring or gravitational systems, resulted in moderate understanding across both genders, while Context B, which incorporated friction and non-conservative forces (e.g., work done by friction), proved more challenging. This may indicate limited ability to coordinate multiple principles in dynamic systems (Liu & Fang, 2017). Students may still be in the novice category, which Bao & Fritchman, (2021) states that novice students have a fragmented knowledge structure, where pieces of knowledge are connected locally to familiar contexts they encounter in textbooks and lectures. When solving problems, they often directly match context features with memorized equations without adequate conceptual understanding. These patterns show that students' conceptual understanding is influenced not only by the physics topic but also by the nature of the contextual framing used in assessments (Tong et al., 2023).

Table 3. Distribution of Students' Conceptual Understanding by Concept, Context, and Gender

Concept	Context	Gender	Understand	Moderate Understand	Not Understand	Total
Work	A	1	4,7%	15,6%	21,9%	42,2%
		2	3,1%	23,4%	31,3%	57,8%
	B	1	18,8%	9,4%	14,1%	42,2%
		2	29,7%	15,6%	12,5%	57,8%
Work and Energy Theorem	A	1	10,9%	10,9%	20,3%	42,2%
		2	23,4%	15,6%	18,8%	57,8%
	B	1	14,1%	9,4%	18,8%	42,2%
		2	7,8%	26,6%	23,4%	57,8%
	C	1	14,1%	15,6%	12,5%	42,2%
		2	26,6%	14,1%	17,2%	57,8%
Mechanical Energy Theorem	A	1	7,8%	17,2%	17,2%	42,2%
		2	4,7%	34,4%	18,8%	57,8%
	B	1	15,6%	4,7%	21,9%	42,2%
		2	14,1%	14,1%	29,7%	57,8%

Interestingly, this study found that gender does not significantly influence conceptual understanding. Statistical analysis using the Mann-Whitney U test revealed no meaningful differences between male and female students for all indicator in terms of their overall understanding of the topic. This supports more recent perspectives on gender equity in science education. Studies by Espinosa et al., (2019); Yadak, (2020); Dew et al., (2021), have shown that when instruction is interactive and conceptually focused, the gender gap in physics performance tends to disappear. These findings challenge earlier narratives that associated male students with superior performance in physics and instead support the view that learning outcomes are more strongly influenced by instructional quality and students' affective engagement rather than gender itself. To ensure equitable and representative findings, studies must account for the multifaceted aspects of gender identity (Fisher et al., 2024). The traditional gender binary, which exclusively categorizes individuals as either male or female, presents significant limitations. This binary approach, while historically prevalent, fails to accurately represent the rich diversity of human gender identities, leading to issues of equity, representation, and the validity of research findings related to conceptual understanding (Wickham et al., 2023).

A particularly notable finding in this study is the significant positive relationship between students' learning interest, both cognitive interest (CI) and emotional interest (EI), and their conceptual understanding. Students who reported higher interest in the subject matter, both in terms of curiosity and emotional connection, tended to perform better on conceptual tasks. The Spearman's rho coefficient for Cognitive Interest (CI) was 0,25 ($p < 0{,}05$), and for Emotional Interest (EI) was 0,42 (p

$< 0,05$), indicating small to medium associations (Oh-Young et al., 2018). Furthermore, when CI and EI were combined into a composite interest score, the correlation with conceptual understanding increased to 0,36 ($p < 0,05$), suggesting a cumulative effect of both cognitive and emotional interest. This finding is supported by the theoretical framework proposed by Harackiewicz et al., (2016); Kahu et al., (2017); Aswegen & Pendergast, (2023), who argue that interest is a key motivational factor that promotes deep engagement with content and facilitates the development of conceptual understanding. The role of emotional interest is particularly compelling, as it often determines whether students invest effort in challenging tasks. Students who feel emotionally connected to learning tasks are more likely to persist, even when the material is difficult (Neve et al., 2023). Situational interest plays a direct role in enhancing knowledge acquisition, especially when the learning environment stimulates both cognitive and emotional involvement (Harackiewicz et al., 2016). These results underscore the importance of designing instruction that is not only cognitively demanding but also emotionally engaging.

Harackiewicz et al., (2016) acknowledged that interest is inherently multidimensional. The study also identified multicollinearity between cognitive and emotional interest, as shown by high VIF values. While this statistical issue limits interpretation of their independent contributions, it also reflects theoretical overlap in how students experience interest. Interestingly, moderated regression analysis showed that gender did not moderate the relationship between interest and conceptual understanding. This suggests that the benefits of learning interest are robust across genders and reinforces recommendations from Kijima et al., (2021) to design instruction that engages all learners through relevance and emotional connection rather than tailoring based on gendered assumptions. Therefore, future research may benefit from modeling interest as a latent construct or exploring composite measures to avoid redundancy and improve predictive clarity.

Although the present findings align with a substantial body of literature, they also contrast with studies suggesting persistent gendered patterns in STEM engagement. Yamtinah et al., (2017) and Kalender et al., (2019), for example, argue that socialization processes and differences in self-efficacy still influence female students' attitudes toward physics. Moraga-pumarino & Salvo-garrido, (2025) similarly noted that male students often report higher self-efficacy, which can affect their performance indirectly. These contradictions highlight the complexity of gender-performance dynamics and underscore the importance of context, both cultural and pedagogical, in interpreting such findings.

D. Conclusions

This study investigated the influence of learning interest and gender on students' conceptual understanding of the work and energy topic in physics. The results revealed that only 28% of students demonstrated a understanding of the concepts, while 30% showed moderate understanding, and a significant 42% were categorized as not understanding. This highlights a substantial gap in conceptual understanding among high school students, particularly in more abstract or complex contexts such as those involving friction or conservation principles. Interestingly, the analysis showed no significant differences in conceptual understanding between male and female students, suggesting that gender alone is not a determining factor in students' grasp of physics concepts. However, item-level trends suggest that contextual framing may interact with students’ cognitive preferences, which merits further exploration.

Moreover, both Cognitive Interest (CI) and Emotional Interest (EI) were found to be significantly correlated with conceptual understanding, underscoring the importance of student motivation and engagement in learning. Students with higher levels of interest, both cognitive and emotional, tended to perform better in concept-based assessments. These findings suggest that enhancing student interest and providing varied conceptual contexts can contribute to improved conceptual understanding in physics. To foster CI and EI, teachers are encouraged to integrate real-world problem-solving activities, relate physics content to students lived experiences, use engaging demonstrations, and support student autonomy in learning tasks.

Despite its contributions, this study has several limitations. First, the number of participants was relatively small, this limits the generalizability of the findings to broaden student populations and educational contexts. Second, the analysis treated gender as a binary variable, which does not capture the full spectrum of students’ gender identities or the potential influence of gendered classroom dynamics. Third, the Student Interest Scale relied on self-reported data, which may be affected by social desirability bias or individual interpretation of items.

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