

Qualitative Analysis of Students' Misconceptions on Energy Conservation in Mechanical Systems

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Abstract: Energy conservation is a fundamental principle in physics, yet numerous studies report that students often hold misconceptions regarding its meaning and application. This study aims to qualitatively explore senior high school students' misconceptions about the conservation of energy in mechanical systems. Data were collected from 36 students in grades X and XI using a four-tier diagnostic test combined with semi-structured interviews. Thematic analysis was employed to identify the types and patterns of misconceptions. Results indicate that students frequently perceive energy as a consumable entity that disappears during processes involving friction, or equate kinetic energy directly with force. Other misconceptions include the belief that energy can be permanently lost in non-conservative systems and that potential energy does not exist unless motion occurs. These findings highlight persistent gaps in conceptual understanding despite formal instruction. The study suggests that explicit teaching strategies, such as conceptual change approaches and multiple representations, are required to address these alternative conceptions.

Keywords: energy conservation, mechanical systems, misconceptions, physics education, qualitative study

Analisis Kualitatif Miskonsepsi Siswa tentang Konservasi Energi pada Sistem Mekanik

Abstrak: Konservasi energi merupakan prinsip fundamental dalam fisika, namun berbagai penelitian melaporkan bahwa siswa sering memiliki miskonsepsi terkait makna dan penerapannya. Penelitian ini bertujuan untuk mengeksplorasi secara kualitatif miskonsepsi siswa SMA mengenai konservasi energi pada sistem mekanik. Data dikumpulkan dari 36 siswa kelas X dan XI dengan menggunakan tes diagnostik empat tingkat yang dipadukan dengan wawancara semi-terstruktur. Analisis tematik digunakan untuk mengidentifikasi jenis dan pola miskonsepsi. Hasil penelitian menunjukkan bahwa siswa sering memandang energi sebagai entitas yang dapat habis selama proses yang melibatkan gesekan, atau menyamakan energi kinetik secara langsung dengan gaya. Miskonsepsi lain mencakup keyakinan bahwa energi dapat hilang secara permanen dalam sistem non-konservatif serta anggapan bahwa energi potensial tidak ada kecuali saat terjadi gerakan. Temuan ini menyoroti adanya kesenjangan pemahaman konseptual yang persisten meskipun telah dilakukan pembelajaran formal. Penelitian ini menyarankan perlunya strategi pengajaran eksplisit, seperti pendekatan perubahan konseptual dan penggunaan berbagai representasi, untuk mengatasi miskonsepsi tersebut.

Kata kunci: konservasi energi, miskonsepsi, pendidikan fisika, sistem mekanik, studi kualitatif

INTRODUCTION

Energy is one of the most fundamental concepts in physics and plays a central role in explaining natural phenomena, solving problems, and constructing coherent scientific knowledge (Duit, 2014). The law of conservation of energy underpins a wide range of mechanical systems, from simple pendulums to complex engineering applications. Despite its significance, research has consistently shown that students often struggle to grasp the abstract and non-intuitive nature of energy, resulting in persistent misconceptions (Soeharto & Csapó, 2022). These misconceptions can hinder their ability to apply the concept of energy conservation meaningfully across different contexts. Recent international benchmarking also shows persistent gaps in applying core physics ideas to novel contexts. The PISA 2022 report highlights difficulties in scientific reasoning and transfer for many students in Indonesia (OECD, 2023).

One of the most common misconceptions is the notion that energy is a consumable entity that disappears once used. Students frequently describe energy as something that is “used up” when objects slow down or stop due to friction, rather than recognizing that energy is transformed into other forms such as heat (Salmadhia et al., 2021). Other studies have reported that students often confuse energy with force, equating kinetic energy with the magnitude of force applied to an object (Rapi et al., 2022). Additionally, misconceptions arise in understanding dissipative systems, where students tend to believe that conservation of energy no longer applies when non-conservative forces, such as friction, are involved (Kaltakci-Gurel et al., 2017).

In the context of mechanical systems, the concept of energy conservation becomes particularly relevant because these systems provide concrete and observable examples of how energy is transformed and transferred. Mechanical systems such as pendulums, springs, inclined planes, and collisions illustrate both the ideal conditions, where energy is perfectly conserved without losses, and the real conditions, where non-conservative forces such as friction or air resistance lead to energy dissipation. In idealized models, mechanical energy remains constant, offering a simplified framework for teaching fundamental principles. However, in real-world mechanical systems, energy transformations are more complex, and students often struggle to reconcile the ideal theory with observed phenomena. This tension between the ideal and the actual provides a strong rationale for focusing on energy conservation in mechanical systems, as it highlights why misconceptions arise and why a deeper qualitative analysis is needed to bridge the gap between students’ intuitive reasoning and scientific understanding.

Previous research has attempted to document these alternative conceptions through various diagnostic instruments. For example, Negoro and Karina (2019) developed a four-tier diagnostic test to identify misconceptions in oscillations and waves, while Bhakti et al. (2023) applied a similar approach to optics. In the domain of energy, Sağlam and Kurnaz (2011) emphasized that misconceptions are not limited to isolated misunderstandings but often form robust mental models that resist change. Beyond prevalence counts, reviews emphasize that robust energy conceptions often resist change without explicit attention to students’ prior models and language (Takeuchi et al., 2020). International studies further confirm the universality of such misconceptions. For instance, Métioui (2023) found that both pre-university and undergraduate students in Canada demonstrated confusion regarding the conservation principle when confronted with real-world situations. Similarly, Braun and Clarke (2021) noted that qualitative approaches, such as thematic analysis of student interviews, provide richer insights into the origins of these misconceptions compared to purely quantitative surveys.

Although these studies have enriched the literature on physics misconceptions, significant gaps remain. First, most investigations into energy misconceptions rely on quantitative survey data, which capture prevalence but do not fully uncover the reasoning processes underlying students' answers, as Pratama (2025) has noted. Second, within the Indonesian context, only a limited number of studies have qualitatively explored how senior high school students conceptualize energy conservation in mechanical systems. The new Kurikulum Merdeka introduced by the Indonesian Ministry of Education emphasizes scientific literacy and the ability to apply physics principles in everyday contexts. However, without addressing entrenched misconceptions, students may continue to experience difficulties in connecting abstract concepts with real-world situations.

Therefore, this study aims to qualitatively analyze students' misconceptions regarding the conservation of energy in mechanical systems. By employing a four-tier diagnostic test in combination with semi-structured interviews, the research seeks to identify the types and patterns of alternative conceptions that persist among high school students. The qualitative approach allows for deeper exploration of students' reasoning processes, thereby contributing not only to the identification of misconceptions but also to understanding why such conceptions arise and how they might be addressed. The findings are expected to inform teachers and curriculum developers in designing instructional strategies that promote conceptual change and strengthen students' scientific literacy in accordance with the goals of Kurikulum Merdeka and global educational standards such as PISA 2022.

THEORETICAL

Understanding students' misconceptions requires grounding in theories of learning, conceptual change, and the nature of scientific knowledge. This section outlines the theoretical foundations relevant to the study, including the constructivist view of learning, the definition and characteristics of misconceptions, and the role of diagnostic instruments in identifying alternative conceptions about energy conservation.

Constructivist Perspective on Learning

From a constructivist perspective, students actively build their understanding of scientific concepts based on prior knowledge and everyday experiences (Driver et al., 1994). Learning is not a simple transfer of knowledge from teacher to learner but rather an active process of restructuring mental models. In the case of energy, students often rely on intuitive notions such as "energy is used up" or "energy disappears," which stem from everyday language and experiences with mechanical systems (Métoui, 2023). These preconceptions, while functional in daily contexts, can conflict with the scientific principle of conservation. Unless addressed through effective teaching strategies, they may persist even after formal instruction (Posner et al., 1982).

Misconceptions and Alternative Conceptions

Misconceptions are defined as ideas that deviate from scientifically accepted concepts yet are held with confidence by learners (Kaltakci-Gurel et al., 2017). In physics education research, the term alternative conceptions is often used to emphasize that these ideas represent alternative frameworks rather than mere errors (Soeharto & Csapó, 2022). Within the context of energy conservation, students often view energy as a tangible substance that can be depleted or destroyed, or they believe that the principle of energy conservation does not apply in non-conservative systems such as those involving friction. Some students also confuse force and energy, treating them as interchangeable quantities, while others assume

that energy only exists when there is visible motion. These misconceptions are considered robust because they are consistent with learners' intuitive reasoning and are further reinforced by everyday experiences and linguistic metaphors (Salmadhia et al., 2021). Multiple representations (graphs–equations–experiments) help students coordinate energy as a state function rather than a “substance” (Busyari et al., 2021; Kurnaz & Sağlam, 2014).

Conceptual Change Theory

The conceptual change model (Posner et al., 1982) provides a framework for addressing misconceptions in science learning. According to this model, students will only replace their misconceptions with scientific concepts when they experience cognitive conflict and recognize the inadequacy of their existing models. Furthermore, the new concept must be intelligible, plausible, and fruitful. Conceptual change is strengthened when learners engage in explicit argumentation and reflective critique of their initial models, not only cognitive conflict (Takeuchi et al., 2020). Pedagogically, constructing warranted scientific explanations is a central mechanism for restructuring ideas (McNeill et al., 2006). In the context of energy conservation, instructional strategies such as multiple representations, inquiry-based learning, and analogical reasoning have been shown to facilitate conceptual change (Rapi et al., 2022).

Diagnostic Instruments for Misconceptions

To uncover misconceptions, researchers have developed various diagnostic tools, including two-tier, three-tier, four-tier, and five-tier diagnostic tests (Bhakti et al., 2023; Treagust, 1988). These instruments combine multiple-choice items with justifications, certainty ratings, and confidence levels to distinguish between lack of knowledge and genuine misconceptions. Recent studies have demonstrated the effectiveness of four-tier diagnostic tests in identifying misconceptions in physics topics such as optics, waves, and mechanics (Negoro & Karina, 2019; Bhakti et al., 2023). When combined with qualitative methods such as semi-structured interviews, these instruments provide deeper insights into students' reasoning patterns and the persistence of alternative conceptions (Braun & Clarke, 2021).

Relevance to Energy Conservation in Mechanical Systems

The theoretical framework emphasizes that misconceptions about energy conservation are not isolated errors but part of broader cognitive structures shaped by prior knowledge and context. Constructivist theory highlights the need to understand students' mental models, while conceptual change theory explains how these models can be modified. Diagnostic tests and interviews serve as effective tools to capture both the prevalence and depth of misconceptions. Together, these frameworks justify the study's qualitative approach to analyzing students' misconceptions on energy conservation in mechanical systems.

METHOD

Research Design

This study employed a qualitative exploratory design within the constructivist paradigm. Such a design was considered appropriate because the focus of the research was not to measure the prevalence of misconceptions statistically, but to explore students' reasoning processes in depth. Qualitative depth aligns with guidance for inquiry into alternative conceptions that traces reasoning trajectories rather than only correctness (Creswell & Poth, 2018; McNeill et al., 2006). The combination of a diagnostic test and

semi-structured interviews enabled the researcher to capture both the surface-level misconceptions and the deeper mental models that students construct when dealing with the principle of energy conservation in mechanical systems.

Participants

The participants consisted of thirty-six senior high school students drawn from two public schools in Central Java, Indonesia. Of these, eighteen students were from Grade X, aged between fifteen and sixteen years, who had recently been taught the topic of work and energy. The remaining eighteen were from Grade XI, aged between sixteen and seventeen years, who had already been introduced to more advanced contexts of energy conservation, including oscillations and non-conservative mechanical systems. Participants were selected using purposive sampling to represent diverse academic backgrounds, as recommended by their teachers, in order to obtain varied perspectives on conceptual understanding. All students were fully informed of the study's objectives, and participation was voluntary. Parental consent and institutional approval were obtained to ensure compliance with ethical standards.

Instruments

Two instruments were employed in the research, namely a four-tier diagnostic test and semi-structured interviews. The diagnostic test comprised ten items adapted from previous studies on physics misconceptions. Each item required students to select an answer to a content question, provide a justification, indicate their certainty level, and state their confidence in their response. This structure made it possible to distinguish between simple errors caused by lack of knowledge and genuine misconceptions. Following the test, twelve students who showed representative answer patterns were invited to participate in interviews. The semi-structured interviews, lasting twenty to thirty minutes each, probed deeper into students' reasoning, asking them to explain why they selected particular answers and how they interpreted energy conservation in different physical contexts. Interviews were recorded, transcribed, and anonymized for analysis.

Data Collection Procedures

Data collection was conducted in three stages. In the first stage, the diagnostic test was administered in a classroom setting under the supervision of physics teachers. The second stage involved analyzing the students' responses to identify those who consistently exhibited misconceptions. The third stage consisted of conducting semi-structured interviews with selected students to gain more comprehensive insights into their conceptual reasoning.

Data Analysis

The data were analyzed using thematic analysis following the procedure described by (Braun & Clarke, 2021). The process began with repeated readings of the diagnostic responses and interview transcripts to achieve familiarization. Initial codes were then generated to categorize responses according to their type of misconception. These codes were subsequently organized into broader themes, such as misconceptions about energy loss, confusion between energy and force, or the belief that energy does not exist in non-conservative systems. The emerging themes were reviewed and refined to ensure coherence across data sources. In the final stage, the themes were clearly defined and supported by illustrative quotations from the student interviews to strengthen the interpretation of findings. To ensure the credibility of the analysis, triangulation was

conducted by comparing diagnostic and interview data. Peer debriefing with two physics education experts was used to review the coding scheme and the consistency of themes. Furthermore, member checking was carried out by asking a selection of students to verify the accuracy of summarized interview responses.

Ethical Considerations

Ethical approval for the research was obtained from the ethics committee of the authors' institution. Students participated voluntarily and were informed of their right to withdraw at any time without academic consequences. All personal data were anonymized, and pseudonyms were used in the reporting of results to guarantee confidentiality and privacy.

RESULTS AND DISCUSSION

Overview of Findings

The results of the four-tier diagnostic test and follow-up interviews indicated that misconceptions about energy conservation remain prevalent among senior high school students. Out of 36 participants, only 27.8% of responses across all test items were scientifically correct with high confidence. In contrast, 54.6% of responses demonstrated clear misconceptions, while the remaining 17.6% reflected a lack of knowledge or random guessing (low confidence responses without consistent reasoning). This shows that more than half of the students hold alternative conceptions about energy conservation, despite having received formal instruction on the topic. Figure 1 presents a visual representation of these proportions, illustrating the dominance of misconceptions compared to scientifically correct and low-confidence responses.

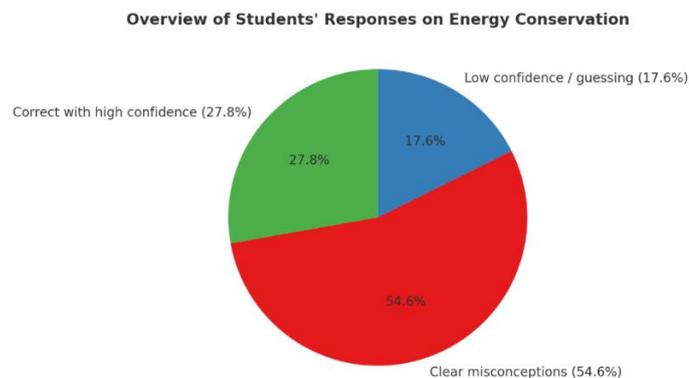


Figure 1. Distribution of Students' Responses in the Diagnostic Test on Energy Conservation

Summary of Misconceptions

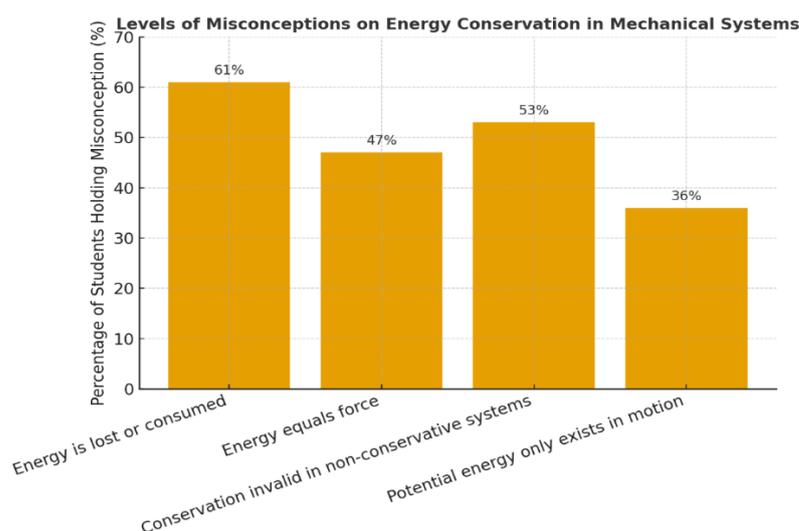
To provide a clearer overview, the categories of misconceptions identified in this study are summarized in Table 1.

Table 1. Categories of Students' Misconceptions on Energy Conservation in Mechanical Systems

No	Category	% of Students Holding Misconception	Representative Error Statement	Scientific Explanation
1	Energy is lost or consumed	61	"Friction destroys energy so the block	Energy is transformed into

No	Category	% of Students Holding Misconception	Representative Error Statement	Scientific Explanation
			finally stops because the energy is finished.”	thermal energy; total energy remains conserved.
2	Energy equals force	47	“If we push stronger, the energy must be stronger too.”	Energy is distinct from force; it is a state function related to velocity/position.
3	Conservation invalid in non-conservative systems	53	“In real life friction cancels conservation.”	Conservation always applies; energy transforms into heat or other forms.
4	Potential energy only exists in motion	36	“At the top of the swing there is no energy because the pendulum is stopped.”	Potential energy depends on position relative to reference, not motion.

In addition to Table 1, Figure 2 illustrates the percentage of students holding each type of misconception. The most prevalent were the view of energy as a consumable entity (61%) and the belief that conservation does not apply in non-conservative systems (53%). This indicates that many students have not yet fully internalized the principle of energy conservation and often confuse energy transformation with energy loss.



Note: Many students exhibited more than one misconception simultaneously.

Figure 2. Levels of Students' Misconceptions on Energy Conservation in Mechanical Systems

Misconception 1: Energy as a Consumable Entity

The most dominant misconception was the idea that energy can be lost or consumed. Approximately 61% of students selected responses consistent with this view, particularly

in items involving frictional motion. One example was a question about a block sliding on a rough surface, where most students stated that the block “loses its energy until none remains.” A Grade X student wrote: “Friction destroys energy so the block finally stops because the energy is finished”. This misconception demonstrates students’ tendency to view energy as a fuel-like substance rather than as a conserved quantity that changes form. The persistence of this misconception is consistent with findings reported by (Métoui, 2023; Salmadhia et al., 2021).

Misconception 2: Equating Energy with Force

Another major misconception, held by 47% of students, was the confusion between energy and force. For instance, when asked to compare two balls pushed with different forces, nearly half of the participants claimed that the ball pushed harder “has more energy because the force is greater.” An interview excerpt illustrates this reasoning: “Energy comes from the force we give. If we push stronger, the energy must be stronger too”. This conflation of force and energy reflects students’ difficulties in differentiating related but distinct physical quantities. (Kaltakci-Gurel et al., 2017) similarly reported that students often treat energy as a direct byproduct of force, which suggests that explicit instruction is needed to clarify the conceptual boundaries between the two.

Misconception 3: Conservation Does Not Apply in Non-Conservative Systems

A total of 53% of students believed that the law of conservation of energy does not hold in real-world systems with friction or resistance. When presented with scenarios involving dissipative forces, these students insisted that conservation is “broken” because energy is destroyed. A Grade XI student explained: “In class we learn conservation, but in real life friction cancels it. That’s why the principle doesn’t work outside ideal conditions”. This result indicates a limited view of conservation as conditional rather than universal. It also reflects the challenge of bridging classroom learning with real-world contexts. As (Rapi et al., 2022) suggested, the use of simulations and visualizations of thermal energy can help students appreciate that conservation always applies, even in the presence of non-conservative forces.

Misconception 4: Potential Energy Exists Only During Motion

About 36% of students expressed the belief that potential energy exists only when an object is moving. This misconception was evident in a pendulum problem, where students claimed that at the highest point “there is no energy because the pendulum is not moving.” A Grade X student stated in writing: “Energy only comes when the pendulum starts to swing. At the top, since it is stopped, there is no energy”. This misconception indicates that many students conceptualize energy only as kinetic and fail to grasp the positional dependence of potential energy. Similar misconceptions were also reported by (Sağlam & Kurnaz, 2011), highlighting the need for instructional approaches that emphasize energy as a state function.

Grade-Level Comparison

The comparison between Grade X and Grade XI students revealed meaningful differences in the way misconceptions manifested. Grade X students were more likely to explain energy phenomena using everyday reasoning, for instance claiming that “energy is finished when the block stops” without referring to conservation principles or energy transformation. In contrast, Grade XI students more frequently attempted to use formal physics terminology such as “mechanical energy” or “work,” but still demonstrated

confusion when distinguishing between energy transformation and energy loss. This indicates that while additional instruction improves students' vocabulary and symbolic reasoning, it does not automatically ensure deeper conceptual integration of conservation across different mechanical contexts. Findings echo work on learning progressions in energy showing slow, stage-wise development with common regressions to substance-like reasoning (Mufti & Sunarti, 2024).

Interview Findings

Semi-structured interviews provided richer insight into students' reasoning processes. Some students described energy in substance-like terms, comparing it to "fuel in a car" that is consumed during motion. Others attempted to apply formulas but misapplied them, for instance equating force directly with energy. Among Grade XI students, a number were able to correctly calculate kinetic or potential energy in certain situations, but they still insisted that "friction cancels conservation" when non-conservative forces were present. These responses indicate a partial but fragmented understanding: while students can recall equations, they often fail to connect them to the universal nature of conservation. The interview findings reinforce the conclusion that misconceptions about energy conservation are not merely gaps in knowledge but represent alternative frameworks shaped by everyday analogies and classroom instruction that emphasizes calculation over conceptual reasoning.

Discussion

These findings align with earlier research that documents similar misconceptions worldwide (Duit, 2014; Kaltakci-Gurel et al., 2017; Métioui, 2023). However, the added value of this study lies in its qualitative analysis that reveals the reasoning behind students' answers. For example, many Indonesian students explicitly linked energy with fuel-based metaphors such as "used up" or "finished," reflecting how language and everyday experience shape conceptual understanding.

The persistence of these misconceptions across grade levels underscores the limitations of conventional instruction that focuses on formula memorization rather than conceptual reasoning. According to the conceptual change model (Posner et al., 1982), such misconceptions can only be overcome if students recognize the inadequacy of their prior beliefs and perceive the scientific model as more plausible and fruitful. Instructional strategies such as inquiry-based learning, multiple representations, and the integration of real-world problems may therefore be required to facilitate conceptual change (Rapi et al., 2022). Furthermore, in the context of Kurikulum Merdeka, these findings are particularly significant. The curriculum emphasizes not only content mastery but also the development of scientific literacy. Addressing misconceptions about energy conservation is essential to ensure that students can apply physics principles meaningfully in both academic and everyday settings.

Instructional Implications

The findings of this study suggest that physics teachers need to design learning activities that confront students' misconceptions about energy conservation directly. One possible strategy is the use of discrepant events, such as experiments where objects slide on different surfaces, allowing students to observe that energy is not destroyed but transformed into heat. Creating this kind of cognitive conflict can encourage students to reconsider the notion of energy as something that "disappears." In addition, inquiry-based learning and modeling approaches can be applied, where students are asked to predict

energy transformations, calculate expected values, and then test these predictions through experiments or simulations. Innovative learning modules designed to actively engage students in the learning process have been shown to improve students' participation and physics learning achievement (Purnomo et al., 2017). In addition, instructional designs that require students to generate, test, and revise causal explanations, particularly related to energy flows, have been found to reduce misconceptions and enhance conceptual understanding (Busyari et al., 2021; Jatmika et al., 2021). The use of multiple representations—equations, graphs, diagrams, and digital simulations—can further strengthen students' conceptual understanding by making the conservation principle visible in different contexts. Virtual laboratories and computer-based simulations can surface otherwise invisible thermal pathways in dissipative processes (Husnaini & Chen, 2019). These approaches are aligned with the flexible design of the Kurikulum Merdeka, which emphasizes contextual and hands-on learning and encourages teachers to allocate more time to science projects or thematic investigations that integrate conceptual reasoning with real-world applications.

Synthesis

This study confirms that students' misconceptions about energy conservation are not simply random errors, but rather structured alternative frameworks shaped by everyday experience and partial scientific reasoning. Many students blend intuitive models, such as fuel-like consumption of energy, with formal physics language, resulting in hybrid explanations that appear correct on the surface but remain conceptually flawed. By uncovering how students actually think, this study highlights the importance of moving beyond rote correction toward deeper engagement with scientific ideas. These findings support the broader goal of developing *scientific literacy*, as emphasized in both PISA assessments and Indonesia's national curriculum. The study contributes to the literature by providing qualitative evidence of students' reasoning trajectories in the domain of energy, showing how misconceptions persist even after instruction. For teachers and curriculum designers, the results underscore the need to design learning experiences that not only correct surface-level errors but also provide opportunities for students to reflect, compare, and reconstruct their understanding of energy conservation through dialogue, inquiry, and model revision.

CONCLUSION AND SUGGESTIONS

This study has qualitatively explored senior high school students' misconceptions regarding the principle of energy conservation in mechanical systems through the use of a four-tier diagnostic test and semi-structured interviews. The findings revealed that misconceptions remain highly prevalent even among students who have formally studied the topic. More than half of the participants consistently demonstrated alternative conceptions, which suggests that conventional instruction has not been fully effective in addressing the underlying difficulties in understanding energy conservation.

Four dominant categories of misconceptions were identified. First, many students perceived energy as a consumable entity that can be lost or destroyed, particularly in contexts involving friction. Second, a significant number of participants equated energy directly with force, reflecting confusion between distinct physical quantities. Third, students frequently argued that the principle of conservation does not apply in non-conservative systems, indicating that they view conservation as conditional rather than universal. Finally, a portion of the students believed that potential energy exists only during motion, failing to recognize its dependence on position relative to a reference point. These

misconceptions were supported by both quantitative test data and qualitative evidence from interview statements.

The persistence of such misconceptions has important implications for physics education. If left unaddressed, these alternative conceptions may hinder students' ability to apply energy conservation across different contexts, thereby limiting their problem-solving skills and scientific literacy. In line with the conceptual change model, it is essential for teachers to create learning experiences that generate cognitive conflict, challenge students' intuitive models, and present the scientific concept as intelligible, plausible, and fruitful. Strategies such as inquiry-based learning, the use of multiple representations, and integration of real-world examples may provide effective pathways for correcting misconceptions. Additionally, virtual laboratories and simulations can be utilized to help students visualize energy transformations, particularly in dissipative systems where the conservation principle is less obvious.

In the broader context of the Kurikulum Merdeka and international benchmarks such as PISA 2022, the results of this study highlight the need for continuous attention to conceptual understanding in physics education. Addressing misconceptions about energy conservation is not only crucial for improving achievement in physics but also for preparing students to apply scientific principles in authentic problem-solving situations.

Implications

The findings suggest several implications for classroom practice. Teachers should employ instructional strategies that directly confront misconceptions, such as discrepant events where students observe energy transformations in both ideal and non-ideal systems. These experiences can create cognitive conflict and stimulate conceptual restructuring, particularly regarding the misconception that energy disappears under friction. Inquiry-based approaches, where students predict energy transformations, calculate expected outcomes, and validate them experimentally, can further strengthen conceptual understanding. Integration with digital simulations and virtual laboratories may also support students in visualizing less tangible forms of energy, such as heat, thereby reinforcing the universality of conservation. Furthermore, the flexible structure of the Kurikulum Merdeka allows teachers to embed project-based and hands-on activities that contextualize energy concepts in real-life applications.

Recommendations

Future research should broaden the scope of participants by involving diverse regions and school types in order to generalize the findings. Longitudinal studies are recommended to evaluate the durability of conceptual change after targeted interventions. Future designs should also be evaluated longitudinally to gauge durability of conceptual change post-intervention (Takeuchi et al., 2020; OECD, 2023). Additionally, further investigations can explore misconceptions in related physics domains, such as thermodynamics and electricity, to identify whether similar conceptual patterns emerge. The integration of technology-based learning tools, including computer simulations and interactive inquiry platforms, should also be examined for their potential to mediate conceptual change. At the classroom level, teachers are encouraged to design diagnostic-based instruction that not only transmits correct scientific knowledge but also reconstructs students' intuitive models through reflection, dialogue, and active engagement. By doing so, physics education can contribute more effectively to the development of scientific literacy as envisioned in both PISA benchmarks and Indonesia's national curriculum.

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