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Reduction of Energy Misconceptions through Handouts and Student Worksheets based on Posner's Conceptual Change Theory

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A B S T R A C T

This study aims to determine the application and effect of handouts and Student Worksheets based on Posner's conceptual change theory in reducing student misconceptions about energy material and the law of energy conservation. Posner's conceptual change theory formulates four requirements for conceptual change to help students change their initial erroneous conceptions into scientific concepts. This research was conducted at MAN 1 Muaro Jambi in February 2025 using a pre-experimental one-group pretest-posttest research design. The instrument used was a five-tier diagnostic test to identify student misconceptions before and after treatment. The Shapiro-Wilk normality test showed that the data were not normally distributed, so the analysis used the nonparametric Wilcoxon Signed-Rank Test. The study's results showed a difference in the number of student misconceptions before and after treatment, marked by a decrease in the percentage of misconceptions by 21.63%. Based on Posner's conceptual change theory, the statistical test results showed fewer misconceptions before and after treatment using handouts and student worksheets ($z = -3.125$). Thus, it can be concluded that using handouts and student worksheets based on Posner's conceptual change theory reduces students' misconceptions about energy and the law of energy conservation.

1. Introduction

Misconceptions often occur in every learning activity. In physics learning, misconceptions can happen in the concept of alternating current, optical equipment, temperature and heat, work and energy (Asmin & Rosdianti, 2021; Frans & Wasis, 2022; Lestari & Hidayat, 2021; Maison, Lestari, & Widaningtyas, 2020; Purwaningtias & Putra, 2020). Misconceptions can occur due to several things, for example because of students' daily experiences when interacting with friends or their environment, because of students' conceptions of objects and events they experience, or come from themselves due to incomplete thinking processes, resulting in flawed understanding (Gumay, 2021; Irianti, 2021). The emergence of this incorrect conception is generally caused by students' preconceptions, which are constructed by several factors: the learning methods used by teachers in teaching, the use of textbooks that are not optimal, information circulating on the internet, incorrect teacher explanations, incomplete observation processes by students regarding a phenomenon, etc. (Rohmah, Priyono, & Sari, 2023; Wahyuni, Maison, & Hidayat, 2023).

One topic prone to misconceptions is the concept of energy and the law of conservation of mechanical energy (Zafitri, Fitriyanto, & Yahya, 2018). Previous studies in the Indonesian context (e.g., at the senior high school level) further highlight this misconception's persistence and specific nature, underscoring the urgent need for effective pedagogical intervention. Previous studies have shown that students often have difficulty understanding the relationship between kinetic energy, potential energy, and the speed of an object, especially when the phenomenon is presented in an everyday context. Students who experience misconceptions are generally unaware that they are experiencing them. Students assume that the conception they have at that time is the correct conception. This conception will continue to develop and can interfere with learning activities (Nurrahmah & Sukarmin, 2023). Thus, action is needed to uncover students' misconceptions through various methods, including using a five-tier diagnostic test.

In this study, five primary forms of misconceptions that occur are discussed: (1) kinetic energy is only influenced by mass or speed, (2) spring potential energy is influenced by spring length, (3) potential energy is only influenced by height, (4) direction of motion affects kinetic energy (5) path length affects speed. These misconceptions are difficult to reduce if teachers only use a conventional expository approach. Thus, a learning strategy is needed that is oriented towards conceptual restructuring, not just information transfer. One approach proven to impact changing students' conceptual understanding is the theory of conceptual change developed by Posner et al. (1982). This theory emphasizes that students' conceptual change can occur based on four conditions: dissatisfaction, intelligibility, plausibility, and fruitfulness.

Posner's conceptual change theory-based teaching strategies have been translated into various forms of teaching media. Using relevant teaching materials, such as handouts and student worksheets, supports improving student conceptual changes (Riswana & Rusmini, 2020). While various studies have explored strategies to address misconceptions, there remains a specific gap in research focusing on the integrated use of handouts and student worksheets meticulously designed according to all four tenets of Posner's conceptual change theory for energy concepts, particularly at the senior high school level. This study aims to fill this identified gap.

In this study, two devices were developed: handouts and student worksheets, which were systematically designed to meet the four requirements for conceptual change. As teaching materials, handouts have the advantage of presenting a summary of important information in a more focused and straightforward way, are easy to understand, and serve as a guide for complex concepts. With targeted modifications, handouts can be arranged according to the desired learning needs, one of which is to reduce student misconceptions in class (Amin & Sulistiyono, 2021). To facilitate deep understanding, students can apply concepts in practical contexts using student worksheets as supporting teaching materials (Suswati, Syaidatul, & Rosmiati, 2021).

Therefore, this study aims to analyze the influence of the handouts and student worksheets based on Posner's conceptual change theory in reducing misconceptions about energy and the law of energy conservation among students at MAN 1 Muaro Jambi.

2. Methodology

Research Target/Subject

The research was conducted at MAN 1 Muaro Jambi in the even semester of the 2024/2025 academic year, with a research sample of 49 students from classes XB and XC. The sample was selected through a simple random sampling technique from three classes available in class X, which had studied energy material and the law of conservation of energy. This study is quantitative with a pre-experimental design and a one-group pretest-posttest design. This design was chosen for its practicality in a real-world classroom setting and its focus on measuring change within the same group of subjects before and after the intervention. The inherent limitations of this design, such as the absence of a control group, will be addressed in the discussion section.

The research procedure involved three stages:

1. **Pretest**: giving students a 5-tier diagnostic test.
2. **Treatment**: using handouts and student worksheets referring to Posner's conceptual change theory. Specifically, the intervention was designed to facilitate Posner's four conditions for conceptual change: (a) **Dissatisfaction** with existing conceptions was prompted through initial diagnostic questions and activities in the worksheets designed to create cognitive conflict with students' prior, often naive, ideas; (b) **Intelligibility** of the new, scientific concepts was ensured by clear, concise explanations in the handouts and structured tasks in the worksheets, using language appropriate for the students' level; (c) **Plausibility** was fostered by connecting new concepts to familiar examples, analogies, and through hands-on or minds-on activities in the worksheets that demonstrated the logical consistency and empirical validity of the scientific conceptions; and (d) **Fruitfulness** was encouraged by providing opportunities for students to apply the new concepts to solve a variety of problems and explain different physical phenomena, thereby demonstrating the explanatory power and broader applicability of the correct conceptions.
3. **Posttest**: giving a 5-tier diagnostic test to measure changes in misconceptions after treatment.

Instruments and Data Collection Techniques

5-Tier Diagnostic Test

Data were collected using a Five-tier diagnostic test to explore student misconceptions. Each question item has five levels of questions, with each level representing: (1) conceptual answer, (3) confidence in answer, (2) reason for answer, (4) confidence in reason, and (5) source of information. The 5-tier diagnostic test can better identify misconceptions, with misconception categories based on student errors: false positives, false negatives, and lack of knowledge.

The diagnostic test consists of 5 items, which represent the forms of misconceptions found in the concept of energy: M1 (changes in kinetic energy depend only on the mass of an object), M2 (changes in kinetic energy depend only on the speed of an object), M3 (changes in potential energy of a spring are only affected by the length of the spring), M4 (changes in potential energy are only affected by the height of an object), M5 (potential energy does not change), and M6 (length of path affects the speed of an object, even though the initial speed is the same). Before its central administration, the instrument underwent content validation by a panel of experienced physics education experts to ensure its alignment with the curriculum and its capacity to accurately diagnose the targeted misconceptions.

Interview Guidelines

To strengthen the quantitative findings, six students were interviewed randomly and semi-structured. Questions asked included students' perceptions of the method, the effectiveness of handouts and student worksheets, and the clarity of the material.

Data analysis Technique

Quantitative Analysis

Based on research statistics, quantitative analysis was conducted to measure changes in students' misconceptions before and after treatment. The research prerequisite test concluded that the data were not normally distributed, and a nonparametric statistical test using the Wilcoxon signed rank test would be conducted to compare scores before and after treatment (Kadir, 2020). Quantitative analysis was performed on two variables: students' correct scores and students' misconceptions (analyzed in three indicators).

Qualitative Analysis

The interview results were analyzed thematically to see whether students' perceptions of the effectiveness of learning tools in helping them reduce misconceptions were consistent.

3. Results and Conclusion

Students' Correct Scores

Table 1 presents data on the percentage of students' correct scores before (pretest) and after (posttest) the treatment. This table directly measures the impact of the intervention on students' ability to answer correctly at various levels of understanding: Tier-1 (correct answers), Tier-1&3 (correct answers and reasons), and All-Tier (correct answers, correct reasons, and confidence in both).
Table 1 shows the research results in the form of students' correct scores during the pretest and posttest.

Table 1. Percentage of Correct Scores

Item	Tier 1		Tier 1&3		All-Tier	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Item 1	12.24	55.10	8.16	32.65	6.12	30.61
Item 2	4.08	57.14	2.04	34.69	2.04	32.65
Item 3	55.10	53.06	51.02	51.02	38.78	51.02
Item 4	12.24	61.22	0.00	34.69	0.00	32.65
Item 5	8.16	40.82	2.04	20.41	2.04	18.37
Mean	18.37	53.47	12.65	34.69	9.80	33.06

Based on the data in Table 1, there is an increase in the percentage of students' correct answers from the pretest to the posttest. The most significant increase in Tier 1 occurred in item 2, from 4.08% in the pretest to 57.14% in the posttest. This shows that after being given treatment, most students understood concepts they had not previously mastered. Meanwhile, in item 3, there was a slight decrease from 55.10% to 53.06%. This decrease is relatively subtle and still in the high category, so students' understanding can be said to be relatively stable. Overall, the average percentage of correct answers in Tier-1 increased from 18.37% in the pretest to 53.47% in the posttest.

Furthermore, in Tier 1 and Tier 3, the highest increase occurred in item 4, from 0.00% in the pretest to 34.69% in the posttest. This shows that many students who initially did not understand the concept can now answer correctly. In item 3, there was no change, which remained at 51.02% before and after treatment, which shows no significant difference, but the level of student understanding remains high. Generally, the average percentage of correct answers in Tier-1&3 increased from 12.65% in the pretest to 34.69% in the posttest.

Finally, in the All-Tier correct score, the highest increase occurred in item 4, from 0.00% in the pretest to 32.65% in the posttest, indicating a significant increase in student understanding after the treatment. The lowest score was recorded in item 3, from 38.78% in the pretest to 51.02% in the posttest. Overall, the average correct answers in the All-Tier increased from 9.80% in the pretest to 33.06% in the posttest.

Students' Misconception Scores

The data presented in Table 2 measure the effectiveness of the intervention in reducing students' misconceptions. This table displays the percentage of misconceptions for each type of misconception identified (M1 to M6) at the Tier-1, Tier-1&3, and All-Tier levels.

Table 2. Percentage of Misconception Scores

Item	Tier-1		Tier-1&3		All-Tier	
	Pre	Post	Pre	Post	Pre	Post
1	61.22	42.86	12.24	20.41	12.24	20.41
2	22.45	2.04	2.04	0.00	2.04	0.00
3	69.39	30.61	6.12	4.08	6.12	4.08
4	2.04	2.04	0.00	0.00	0.00	0.00
5	8.16	24.49	8.16	16.33	8.16	16.33
6	43.54	12.93	26.53	3.40	23.13	3.40
Mean	34.47	19.16	9.18	7.37	8.62	7.37

Overall, the intervention showed success in reducing students' misconceptions. The average misconception in Tier-1 decreased from 34.47% (medium category) to 19.16% (low category). A decrease also occurred in the average misconception of Tier-1&3 (from 9.18% to 7.37%) and All-Tier (from 8.62% to 7.37%), although both were already in the low category in the pretest. The effectiveness of the intervention varied between types of misconceptions. A significant decrease was seen in misconception M2 (changes in kinetic energy only depend on the object's speed), where in Tier-1 the percentage dropped from 22.45% to 2.04%, and even reached 0% in Tier-1&3 and All-Tier. Misconception M3 (changes in potential energy of the spring are only affected by the length of the spring) also showed a substantial decrease in Tier-1, from 69.39% to 30.61%. Similarly, misconception M6 (path length affects the speed of an object, even though the initial speed is the same) experienced a significant decrease at all tier levels, for example, in Tier-1 from 43.54% to 12.93%. These results indicate that these aspects of misconceptions are responsive to the learning strategies applied.

However, there are more complex findings. For misconception M1 (changes in kinetic energy only depend on the mass of the object), although there was a decrease in Tier-1 (from 61.22% to 42.86%), the percentage of misconceptions in Tier-1&3 and All-Tier increased from 12.24% to 20.41%. This phenomenon shows that although fewer students answered incorrectly at the surface level, the number of students who had wrong reasoning and believed in it increased. This suggests that efforts to correct misconception M1 may have inadvertently strengthened alternative reasoning that was wrong but considered reasonable by students.

The most striking finding that requires special attention is the consistent increase in misconception M5 (potential energy does not change) across all tier levels. In Tier-1, misconception M5 increased from 8.16% to 24.49%, and similar increases also occurred in Tiers-1&3 and All-Tier. This increase indicates that the intervention failed to address misconception M5, potentially reinforcing it or creating new confusion. This may be related to how the concept of relative and changeable potential energy is explained in the handout and student worksheets, which may be strongly contrary to students' intuitions or misinterpreted. This phenomenon may lead to the suspicion of a backfire effect, where correction efforts reinforce false beliefs, or an iatrogenic effect, where the intervention contributes to undesirable outcomes. Additional data from the study show that the source of misconceptions from the "teacher's explanation" (in this case, the researcher) slightly increased after the posttest, which may be relevant in this context. Meanwhile, misconception M4 (changes in potential energy are only influenced by the object's height) was relatively stable and low before and after treatment.

Understanding Change Pattern Analysis: False Positive (FP), False Negative (FN), and Lack of Knowledge (LK)

Analysis of the False Positive (FP), False Negative (FN), and Lack of Knowledge (LK) categories provides a more detailed picture of the quality of students' understanding and the changes that occurred after the intervention. Data for this analysis are presented in Table 3.

Table 3. Percentage of False Positives, False Negatives, and Lack of Knowledge

Item	FP		FN		LK	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Item 1	4,08	22,45	26,53	18,37	61,22	26,53
Item 2	2,04	22,45	12,24	8,16	83,67	34,69
Item 3	4,08	2,04	0,00	6,12	44,90	40,82
Item 4	12,24	26,53	6,12	6,12	81,63	32,65
Item 5	6,12	20,41	8,16	6,12	83,67	53,06
Mean	5,71	18,78	10,61	8,98	71,02	37,55
Category	Low	Low	Low	Low	High	Medium

The most significant decrease was observed in the Lack of Knowledge (LK) category, where the average percentage of students who had no knowledge or a completely wrong understanding decreased drastically from 71.02% (high category) to 37.55% (medium category). This significant decrease occurred in almost all test items, except for Test Item 3, which had a relatively small decrease. This is a strong indicator of the success of the intervention in building basic understanding and reducing the number of students who had no conceptual foundation.

In contrast, the average False Positive (FP), where students answer correctly but with the wrong reason, increased from 5.71% to 18.78%, although both are still in the low category. A quite striking increase in FP occurred in Question Item 1 (from 4.08% to 22.45%), Question Item 2 (from 2.04% to 22.45%), Question Item 4 (from 12.24% to 26.53%), and Question Item 5 (from 6.12% to 20.41%). This increase in FP, which coincided with an increase in correct answer scores on these items (Table 1), implies that some students may have moved from the LK or incorrect answer condition to being able to choose the correct answer. However, the underlying reasoning is not yet entirely accurate. This indicates the possibility of superficial understanding. The average in the False Negative (FN) category, where students answer incorrectly even though their reasoning is correct, decreased slightly from

10.61% to 8.98%. This slight decrease indicates that students have become slightly better at aligning correct reasoning (if they have it) with the correct answer choice.

Combining a significant LK decrease with an FP increase on some test items is an interesting pattern. This suggests that the intervention successfully moved some students out of the "no idea" state, but some of them may have landed in the "know the right answer, but do not understand why" or "know the right answer, but with the wrong reasoning" state. This may represent a transitional stage in the conceptual change process, where introducing the correct answer through the handout and student worksheets occurs before internalizing deep scientific reasoning. The implication is that future interventions may need to emphasise the development of correct scientific reasoning, rather than just introducing the correct answer. The percentages of students who experienced FP, FN, and LK at pretest and posttest are presented in Figure 1.

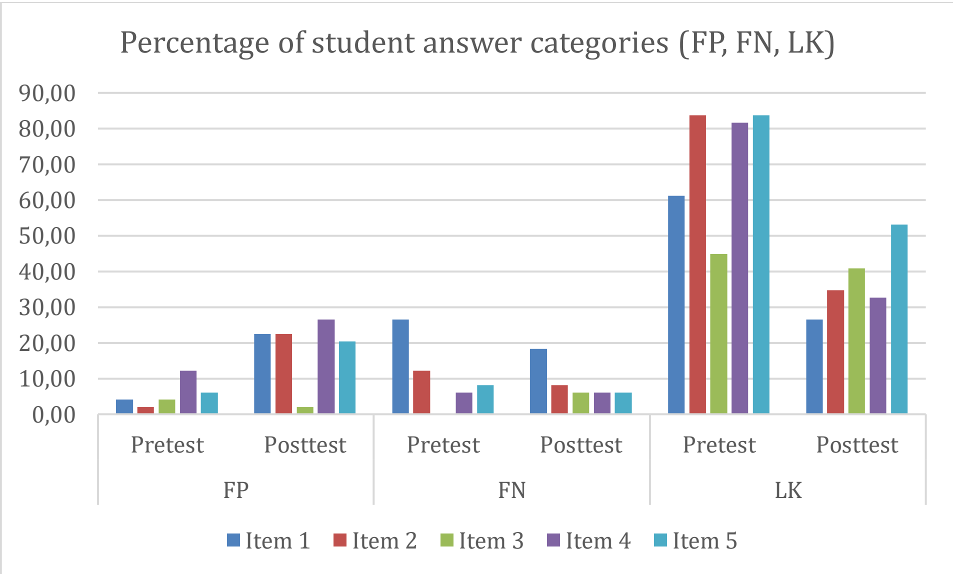

Figure 1. Comparison of Pretest-Posttest

Effectiveness of Interventions in Reducing Misconceptions

Overall, the intervention had a positive impact on students' understanding. This was not only reflected in the decrease in the percentage of general misconceptions by 21.63%, but was also confirmed by statistical significance through the Wilcoxon Signed Rank test ($z = -3.125$; $p < 0.05$). This finding indicates that the changes observed in students' understanding are most likely the result of the intervention given, not a coincidence. The very significant decrease in the Lack of Knowledge (LK) category from 71.02% to 37.55% is one of the most substantial evidence of the success of the intervention. This shows that the learning approach based on Posner's conceptual change theory, supported by handouts and student worksheets, is practical in building a foundation of initial knowledge for many students. This process aligns with the initial stage in Posner's model, namely, creating dissatisfaction with the absence of concepts or wrong concepts and presenting new concepts that can be understood (intelligible). Handouts designed to present information concisely and structured student worksheets likely contributed significantly to this achievement. Building this foundational knowledge is crucial before learners achieve a more profound understanding and correct more subtle or complex misconceptions.

The increase in the False Positives (FP) percentage on several test items, even though the average correct score also increased, highlights an important challenge in achieving accurate and profound conceptual change. When students answer correctly but with the wrong reason, they may only achieve a superficial understanding or "recognize the answer pattern" presented in the learning material, without mastering the underlying concept. This phenomenon underlines that providing correct information through handouts and student worksheets does not automatically guarantee that students will integrate it correctly into their existing thinking framework. There is a possibility that the process of "assimilating" new information into existing (and possibly erroneous) conceptual schemes occurs, rather than the process of "accommodation" (fundamental restructuring of the scheme) as expected in Posner's theory of conceptual change. If only the answer seems intelligible to students, but the underlying scientific reasoning is not considered plausible or well-connected, then an increase in FP can occur. This is a sign that the cognitive conflict experienced by students may not have been fully resolved, or its resolution is still shallow.

On the other hand, the decrease in the False Negative (FN) rate, although not as significant as the changes in LK or FP, is still a positive indication. This shows that students who understand the reasons can better choose the correct final answer. This could indicate increased coherence in their understanding or confidence in applying their knowledge, even though it may not be perfect.

The fact that the primary source of misconceptions still comes from students' "personal thinking", even after the intervention (74.47% in the pretest and 76.00% in the posttest), emphasizes how intense and persistent the initial conceptions held by students are. Misconceptions are often not simply a lack of information, but rather active constructions built by students based on their experiences and interpretations of the world. The persistence of this personal thinking suggests that dissatisfaction with old concepts may not be strong enough, or that the new scientific concepts presented are not considered plausible or fruitful enough to completely replace these ingrained personal constructions. Therefore, future interventions may require more intensive and diverse strategies to effectively challenge and restructure these established personal thoughts.

Effectiveness of Interventions in Reducing Misconceptions

Misconception M2 (change in kinetic energy depends only on the speed of an object) showed a very drastic decrease across all tier levels. This success was likely due to the effectiveness of the cognitive conflict presented (e.g., through a video of two identical cars with different speeds) and the clarity of the explanation of the concept of kinetic energy that relates mass and speed.

Misconception M3 (change in potential energy of a spring is only affected by the length of the spring) also experienced a substantial decrease, especially at Tier-1. The use of PhET simulations in learning appeared to be effective in creating dissatisfaction with old concepts and helping learners better understand the factors that affect the potential energy of a spring.

Misconception M6 (length of path affects the speed of an object, even though the initial speed is the same) also showed a significant decrease across all tier levels. Video illustrations showing children sliding on different tracks but from the same height are likely to successfully challenge students' initial intuitions and facilitate understanding of the law of conservation of mechanical energy.

Misconception M1 (change in kinetic energy depends only on the object's mass) shows an interesting pattern. There is a decrease in Tier-1 (which means more students answered correctly on the surface), but the percentage of misconceptions in Tier-1&3 and All-Tier increases. This "paradox" indicates that students may learn to choose the "correct" answer without a deep understanding of the reasoning, or even that the incorrect reasoning becomes more entrenched and believed after the intervention. The explanation of the relationship between work, mass, velocity, and change in kinetic energy may be oversimplified by students or misinterpreted, so they focus too much on one variable (mass) with a higher belief in the incorrect reasoning. The intervention may have succeeded in the intelligibility stage of the answer, but failed to achieve plausibility for the correct reasoning.

Misconception M5 (potential energy does not change) shows an increase in percentage at all test levels. This is the most problematic finding and suggests the possibility of an "iatrogenic effect" or "backfire effect" of the intervention for this specific misconception. Explanations about the relative nature of potential energy or how it can change (e.g., depending on a reference point or a change in the system configuration) may confuse or misinterpret learners, reinforcing their initial belief that potential energy is absolute or unchanging in a given context. Cognitive conflicts designed for this concept (e.g., illustrations of coconuts at different heights versus coconuts and mangoes of different masses at the same height) may fail to create appropriate dissatisfaction or may even lead to misinterpretation. Potential energy being negative or dependent on a reference point is often challenging to understand and counterintuitive. Learners may "retain" or even reinforce their old ideas if not explained very carefully and with appropriate analogies.

Misconception M4 (change in potential energy is only affected by the height of an object) showed minimal change and remained at a low level both before and after the treatment. This may be because this misconception was not dominant in the initial study sample or had been overcome through previous learning.

The general findings of this study, which show that learning strategies based on conceptual change theory can effectively reduce students' misconceptions, align with various previous studies in physics education. For example, research by Surtiana et al. (2021) who used the Virtual Conceptual Change Laboratory (VCCLAB), Hidayati (2015) who developed handouts based on the Driver and

Oldham conceptual change model, Frans & Wasis (2022) who implemented PhET-based LKPD, and Parwati, Makhrus, & Gunada (2019) who emphasized the importance of cognitive conflict, all reported positive impacts of similar approaches in overcoming misconceptions. Using handouts and LKPD as supporting media for the conceptual change process has also been beneficial in other studies, as reported by Amin & Sulistiyono (2021) and Suswati et al. (2021). This consistency strengthens the external validity of the findings of this study, indicating that the conceptual change-based approach is a promising strategy and can be applied in various physics learning contexts using various tools.

Despite the general consistency, the magnitude of the misconception reduction percentage achieved in this study (21.63%) may differ when compared to other studies (e.g., Surtiana et al. (2021) reported a reduction of 45.35%). Such variation is natural and can be attributed to various factors, including differences in the physics topics focused on, the specific design and duration of the intervention, characteristics of the student population, and the type and sensitivity of the diagnostic instrument used.

One methodological contribution of this study is the use of a five-tier diagnostic test. This instrument allows for a more granular and in-depth analysis of student understanding, including assessing students' confidence level in their answers and the reasons they provide. This provides a richer picture of the structure of misconceptions and how learners' beliefs about misconceptions can influence the process of conceptual change, beyond what can be revealed by lower-level diagnostic tests. Furthermore, despite interventions designed based on Posner's theory, the specific findings of increased misconception M5 (potential energy does not change) and complex response patterns for misconception M1 (regarding the role of mass in kinetic energy at the reasoning level) provide important new insights. These findings highlight the potential limitations of standard models of conceptual change and indicate that not all misconceptions will respond uniformly to the same interventions. Interventions may inadvertently reinforce certain misconceptions or introduce new confusion if not implemented with great care and tailored to the specific nature of the misconceptions. This opens up important areas for further research into the mechanisms by which some misconceptions are particularly resistant to change and how interventions can be designed to avoid counterproductive effects.

4. Conclusion

The results of the study showed that the implementation of teaching materials designed to create dissatisfaction with old concepts, present new concepts that are clear and reliable, and demonstrate the usefulness of scientific concepts, successfully provided a positive influence. Overall, there was a significant decrease in misconceptions in students after the intervention. However, the effectiveness of the intervention varied; some misconceptions could be substantially reduced, but others showed resistance or even increased, indicating that deep understanding and complete conceptual change are complex processes that require more specific strategies for certain misconceptions. Further research is recommended to explore factors that influence misconception resistance, develop more targeted interventions, and expand the scope of research on more diverse topics and samples.

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