Online Learning in Educational Research
Volume 5, Issue 1, 25-40.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index
DOI: 10.58524/oler.v5i1.606

Breaking Misconceptions: Technology-Integrated MORE Model for Meaningful Learning of Momentum and Impulse

Rizal Adimayuda
Universitas Pendidikan Indonesia, INDONESIA

Andi Suhandi*
Universitas Pendidikan Indonesia, INDONESIA

Achmad Samsudin
Universitas Pendidikan Indonesia, INDONESIA

Endi Suhendi
Universitas Pendidikan Indonesia, INDONESIA

Agus Setiawan
Universitas Pendidikan Indonesia, INDONESIA

Nuzulira Janeusse Fratiwi
Universitas Pendidikan Indonesia, INDONESIA

Article Info

Article history:

Received: January 15, 2025
Revised: March 20, 2025
Accepted: March 30, 2025
Published: June 15, 2025

Keywords:

Impulse;
Meaningful learning;
Misconceptions;
Momentum;
T-MORE model.

Abstract

Misconceptions in physics, particularly in topics like momentum and impulse, pose significant barriers to meaningful learning, as students often rely on everyday experiences that contradict scientific principles. Addressing these misconceptions is crucial for improving students' understanding and application of physics concepts in real-world contexts. This study examines the effectiveness of the Technology-Integrated Modification, Observation, Reflection, and Evaluation (T-MORE) model in addressing misconceptions about momentum and impulse through a convergent parallel mixed-methods design. A total of 22 first-semester undergraduate students participated in this study, receiving instruction incorporating videos, PhET simulations, and AI-assisted reflection tools. Conceptual understanding was measured using the Four-Tier Momentum and Impulse Misconception Diagnostic Test (FT-MIMDT). The McNemar test confirmed a statistically significant improvement, while the Reduction of Misconception Quantity (RMQ) indicated a high reduction in misconceptions. Qualitative analysis revealed changes in students' misconceptions regarding momentum conservation and impulse-momentum relationships after instruction. These findings confirm the effectiveness of T-MORE in improving conceptual understanding and reducing misconceptions in momentum and impulse. The implementation of T-MORE can be further optimized by incorporating collaborative discussion sessions and adaptive formative assessments to ensure that all students can reconstruct their understanding more comprehensively.

To cite this article: Adimayuda, R., Suhandi, A., Samsudin, A., Suhendi, E., Setiawan, A., & Fratiwi, N. J. (2025). Breaking misconceptions: Technology-integrated MORE model for meaningful learning of momentum and impulse. *Online Learning in Educational Research, 5*(1), 25-40

INTRODUCTION

Misconceptions in physics have long been a major obstacle to meaningful learning, particularly in abstract topics such as momentum and impulse. These misconceptions arise when students rely on everyday experiences to interpret physical phenomena, forming intuitive understandings that often contradict scientific principles (Bessas et al., 2024; Samsudin et al., 2023; Stefanou et al., 2024). Without proper intervention, these misunderstandings persist and become

* **Corresponding author:**
Andi Suhandi, Universitas Pendidikan Indonesia, Indonesia. ✉ andi_sh@upi.edu

deeply ingrained, making it difficult for students to grasp the correct concepts even after formal instruction. Many students, for instance, believe that a heavier object must always have more significant momentum regardless of its velocity or that momentum is lost after a collision rather than conserved (Adimayuda et al., 2020; Amalia et al., 2019; Sakinah et al., 2023; Setiani et al., 2023; Triyani et al., 2019). Another common misunderstanding is the belief that impulse depends solely on force, without considering the time interval over which the force is applied (Kaniawati et al., 2021). These misconceptions are widespread and highly resistant to change, as students tend to interpret new information in ways that reinforce their preexisting beliefs rather than revising their understanding based on scientific reasoning.

The persistence of these misconceptions becomes even more concerning when examining their impact on students' ability to apply physics principles in real-world contexts. A preliminary study conducted in one of university in Garut (Indonesia) found that 65.91% of students demonstrated misconceptions about momentum and impulse, with the most common misconception (77.27%) being the belief that two colliding objects will always move with the same velocity after impact. These findings align with previous research, which indicates that many students struggle to differentiate between momentum and kinetic energy, leading them to incorrectly assume that objects with the same kinetic energy must also have the same momentum (Brundage et al., 2023; Maries et al., 2023; Mufit, 2018; Rivaldo et al., 2020; Tong et al., 2023). Additionally, students often fail to recognize the vector nature of momentum, leading to incorrect predictions about the motion of objects after collisions. Such misconceptions not only hinder students' ability to solve physics problems correctly but also limit their capacity to make informed decisions in fields such as engineering, biomechanics, and automotive safety, where understanding momentum and impulse is crucial (Minichiello et al., 2018).

Addressing these misconceptions requires more than just presenting students with scientifically accurate explanations, as research has shown that simply exposing students to correct concepts does not guarantee conceptual change. Several instructional strategies have been developed to reduce misconceptions, one of which is the Conceptual Change Model (CCM) introduced by Posner et al. (1982). This model emphasizes the need for cognitive conflict between students' initial understanding and the scientifically accurate concept to facilitate conceptual change. A study Yumuşak et al. (2015) showed that using Conceptual Change Texts (CCT) in learning can improve students' understanding by explicitly contrasting their misconceptions with the correct concepts. Additionally, the use of Interactive Lecture Demonstrations (ILDs) has proven effective in reducing misconceptions by allowing students to test their predictions against real experimental results (Estipular & Roleda, 2018). Similarly, studies by Ndumanya et al. (2021) and Schoormann et al. (2023) highlighted the effectiveness of technology-integrated approaches, such as Inquiry-Based Learning (IBL) combined with computer simulations, in addressing misconceptions about momentum and impulse. These findings underscore the value of integrating various instructional strategies, including technological tools, to facilitate meaningful learning and conceptual change.

Technology-based approaches have also been increasingly employed to specifically address misconceptions in physics (Surya et al., 2022; Sari et al., 2022). Diani et al. (2018) demonstrated that using PhET Interactive Simulations helps students confront their misconceptions by allowing them to test and revise their incorrect predictions through interactive experimentation. Similarly, Ghadiri et al. (2016) found that computer simulations based on constructivist approaches have also been found effective in removing physics misconceptions among high school students. Furthermore, Nyoman et al. (2024) suggested that implementing Intelligent Tutoring Systems (ITS) with AI-based adaptive feedback assists students in identifying and correcting their misconceptions by providing targeted prompts and explanations tailored to their errors. While these studies highlight the potential of technology in facilitating conceptual change through interactive and adaptive learning experiences, they primarily focus on isolated interventions without a comprehensive, structured approach to misconception remediation. Existing models often lack an explicit mechanism that regularly guides students through the key cognitive processes of misconception modification, observation, reflection, and evaluation.

To address this gap, an instructional model is required that not only explicitly targets misconceptions but also ensures that students engage in meaningful learning to construct a more robust conceptual understanding. The increasing role of technology in physics education provides an opportunity to develop a structured approach that systematically integrates digital tools to facilitate conceptual change (Banda & Nzabahimana, 2021). Therefore, this study proposes the Technology-Integrated MORE (T-MORE) Model, which builds upon previous approaches by integrating videos, animations, and simulations into a four-phase framework: Modification, Observation, Reflection, and Evaluation (MORE). Unlike ILDs and CCTs, which often operate linearly, the T-MORE Model employs a dynamic, iterative process that actively engages students in diagnosing, challenging, and reconstructing their misconceptions through real-time interaction with technology-enhanced representations. Unlike prior technology-based interventions that primarily serve as supplementary tools, the T-MORE Model systematically embeds technology within a structured learning process to actively guide students in confronting, analyzing, and resolving misconceptions. By leveraging digital media and interactive simulations, this model not only exposes students to scientifically accurate representations but also encourages them to reflect on their prior knowledge, test their understanding, and iteratively refine their conceptual framework.

This study examines the effectiveness of the Technology-Integrated MORE Model in fostering meaningful learning to reduce students' misconceptions of momentum and impulse. The findings provide empirical support for structured, technology-enhanced interventions in physics education. By integrating technology with conceptual change strategies, this model aims to enhance student engagement and conceptual mastery. Beyond correcting misconceptions, it promotes a deep, transferable understanding of physics. Ultimately, this research offers an evidence-based framework for educators, leveraging videos, animations, and simulations to create an interactive and effective learning experience aligned with cognitive processes essential for science mastery.

METHOD

Research Design

This study employs a mixed-methods research design with a convergent parallel approach (Demir, 2018) to evaluate the effectiveness of the Technology-Integrated MORE Model in addressing misconceptions about momentum and impulse. In this design, quantitative and qualitative data are collected simultaneously, analyzed separately, and then merged to provide a comprehensive understanding of students' conceptual change. The quantitative component focuses on classifying students' conceptual understanding using pre-test and post-test scores, while the qualitative component explores changes in students' misconceptions. A mixed-methods approach is chosen to ensure that numerical improvements in conceptual understanding are supported by insights into the processes of students' misconception changes, providing a more comprehensive evaluation of learning outcomes.

Participants

The participants in this study consist of 22 first-semester undergraduate students enrolled in a basic physics course at a university in Garut, Indonesia. The participants range in age from 18 to 19 years old, with a gender distribution of 14 male students and 8 female students. All participants come from a single class, which serves as the experimental group. These students have previously studied momentum and impulse in high school but have not yet received focused instruction on the topic at the university level. Their background ensures that they have foundational knowledge while still being at a stage where misconceptions about momentum and impulse are commonly found.

Technology-Integrated MORE Model

The Technology-Integrated MORE (T-MORE) Model systematically embeds videos, animations, and simulations into a structured four-phase framework: Modification, Observation, Reflection, and Evaluation, as illustrated in Figure 1.

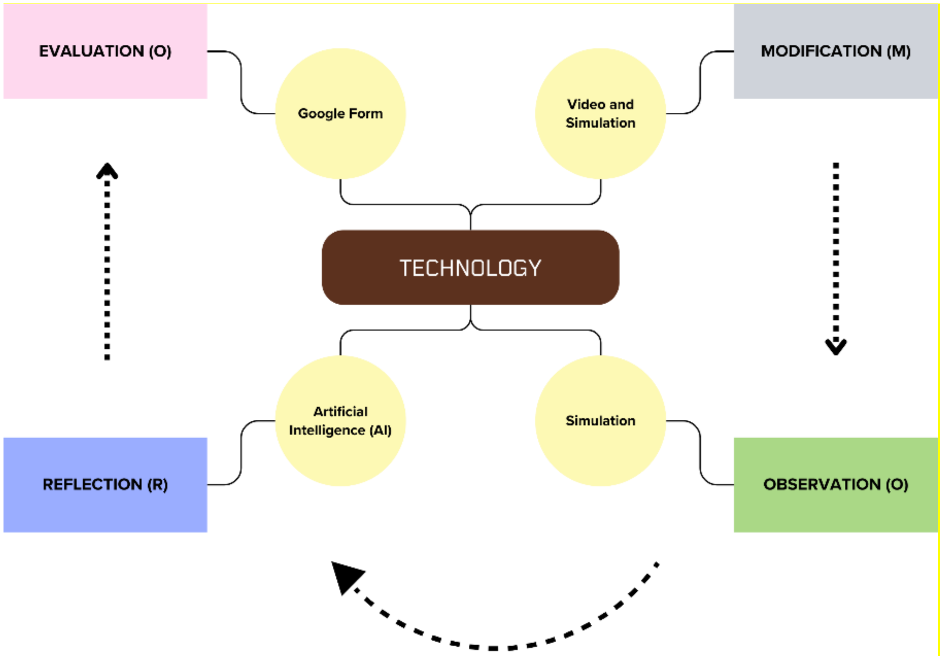

Figure 1. Design of Technology-Integrated MORE (T-MORE) Learning Model

This model begins with the Modification phase, where students interact with multimedia resources to challenge their misconceptions through guided exploration and structured problem-solving. The Observation phase involves inquiry-based activities that help students develop an accurate understanding of momentum and impulse by analyzing visual data, testing predictions, and manipulating simulations. In the Reflection phase, students evaluate their evolving understanding through discussions, written explanations, and self-assessment. Finally, the Evaluation phase assesses conceptual change using formative and summative measures to ensure misconceptions are replaced with scientifically accurate knowledge.

The four interconnected phases of the MORE model and their respective technology integrations are summarized in Table 1.

Table 1. Phases of the Technology-Integrated MORE Model

Phase	Description	Technology Integration
Modification	Students engage with multimedia resources that illustrate real-world applications and experimental demonstrations of momentum and impulse. These materials expose inconsistencies in prior conceptions, prompting students to question their understanding.	Videos and PhET Interactive Simulations presenting misconceptions and real-world examples of momentum and impulse.
Observation	Inquiry-based activities guide students through PhET simulations, allowing them to manipulate variables, test predictions, and observe real-time momentum conservation, impulse-momentum relationships, and collision dynamics.	PhET Interactive Simulations for virtual experiments and real-time data visualization.
Reflection	Students articulate their learning progress through self-assessment, structured discussions, and AI-assisted feedback tools, helping them compare their evolving understanding with their initial misconceptions.	ChatGPT-based tutor for automated feedback and conceptual clarification.
Evaluation	Students complete the Four-Tier Momentum and Impulse Misconception Diagnostic Test (FT-MIMDT) as a post-test to measure conceptual change and identify persistent misconceptions.	Google Forms test administration.

Instruments

The instrument used in this study is the Four-Tier Momentum and Impulse Misconception Diagnostic Test (FT-MIMDT), which is designed to identify students' misconceptions and measure conceptual changes through a structured four-tier format. The first tier consists of a multiple-choice question assessing factual knowledge of momentum and impulse. The second tier measures students' confidence in their answer from the first tier, where they must choose between "sure" or "not sure." The third tier requires students to provide a reason for their answer in the first tier. The fourth tier asks students to indicate their confidence in their explanation from the third tier, again selecting "sure" or "not sure." This format allows for a detailed classification of students' conceptual understanding and confidence levels, as shown in Figure 2.

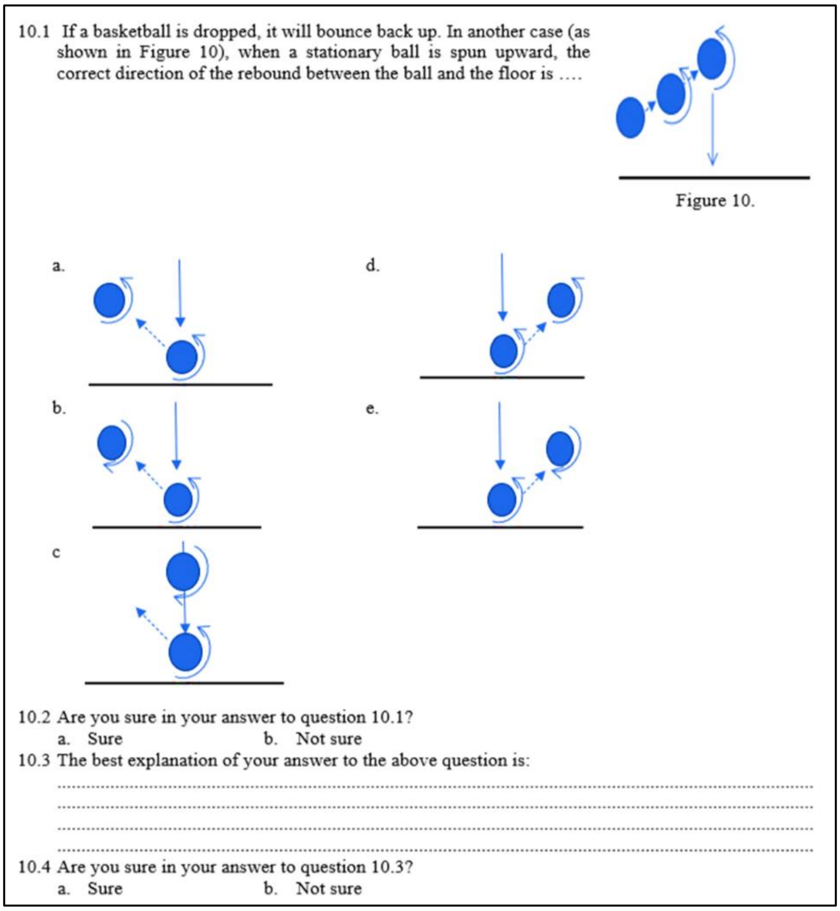
10.1 If a basketball is dropped, it will bounce back up. In another case (as shown in Figure 10), when a stationary ball is spun upward, the correct direction of the rebound between the ball and the floor is ….

Figure 10.

a.

b.

c

d.

e.

10.2 Are you sure in your answer to question 10.1?
a. Sure b. Not sure

10.3 The best explanation of your answer to the above question is:
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

10.4 Are you sure in your answer to question 10.3?
a. Sure b. Not sure

Figure 2. Example of FT-MIMDT

The FT-MIMDT is administered twice, as a pre-test before instruction and a post-test after instruction, to measure changes in students' conceptual understanding. The validity of the FT-MIMDT is established through expert validation involving three physics education specialists, who assess the content to ensure that the test accurately diagnoses misconceptions and aligns with fundamental concepts of momentum and impulse. Content validity is confirmed by aligning test items with common misconceptions reported in previous studies, ensuring that the instrument effectively targets prevalent misunderstandings. Construct validity is examined through an item analysis, verifying that each tier effectively captures different aspects of students' conceptual understanding. The final version of the instrument achieves a content validity index (CVI) of 0.86, indicating a high level of agreement among experts. The reliability of the instrument is evaluated using Cohen's Kappa coefficient, which measures inter-rater agreement in classifying students' conceptions. The obtained Kappa value of 0.78 indicates strong agreement, confirming the consistency of the classification process.

Data Analysis

Data analysis consists of descriptive statistics and non-parametric tests for the quantitative component, while the qualitative component explores students' misconceptions. The quantitative analysis focuses on determining the percentage of students in each conceptual category before and after instruction. To analyze students' conceptual understanding, their conceptions are classified into three categories based on their responses in the four-tier diagnostic test. The classification criteria are presented in Table 2.

Table 2. Classification of Student Conceptions Based on FT-MIMDT

Conception Type	Tier 1 (Answer)	Tier 2 (Confidence in Answer)	Tier 3 (Reasoning)	Tier 4 (Confidence in Reasoning)
Scientific Conception (SC)	Correct	Sure	Correct	Sure
Misconception (MC)	Incorrect	Sure	Incorrect	Sure
No Conception (NC)	Any other combination			

Then, the percentage of students in each category for every question in both the pre-test and post-test is calculated. To evaluate the significance of conceptual shifts, McNemar's test is used. This test analyses whether there is a statistically significant change in students' misconceptions after instruction by comparing the number of students who shifted from incorrect to correct answers and vice versa. Decision-making in McNemar's test is based on the chi-square value ($\chi 2$) calculated from the test formula. If the p-value is less than 0.05, the null hypothesis is rejected, indicating a significant reduction in misconceptions. Conversely, if the p-value is greater than 0.05, it suggests that the instructional intervention did not lead to meaningful conceptual change.

To complement statistical significance, effect size is reported using Cohen's g, a measure suited for McNemar's test, which quantifies the magnitude of the observed change. Additionally, 95% confidence intervals (CI) for the estimated effect size are provided to assess the precision and reliability of the effect estimate. Effect size interpretation follows Cohen's guidelines, where 0.2 indicates a small effect, 0.5 is a moderate effect, and 0.8 or higher is a large effect (Bakker et al., 2019).

The reduction in misconceptions is analyzed using the Reduction of Misconception Quantity (RMQ), an adaptation of the normalized gain formula (Dalila et al., 2022), calculated as follows:

$$RMQ = \frac{(\%pretest - \%posttest)}{(\%pretest - \%ideal)} x 100\% \qquad (1)$$

The RMQ values are then interpreted into three categories, as shown in Table 3.

Table 3. Interpretation of RMQ Values (Dalila et al., 2022)

RMQ Value (%)	Category
70 < RMQ ≤ 100	High
30 < RMQ ≤ 70	Moderate
0 < RMQ ≤ 30	Low

The qualitative analysis involves thematic analysis of students' explanations in the fourth tier of the FT-MIMDT. Recurring themes in their reasoning are categorized to identify patterns of conceptual change, persistent misconceptions, and engagement with the MORE model. A comparative analysis between pre-test and post-test explanations examines how each student's misconceptions change, providing a deeper understanding of individual learning trajectories. The type of conceptual change experienced by each student is classified based on Table 4.

Table 4. Classification of Conceptual Change

Conceptual Change	Description
Complete Change (CoC)	Misconception in pre-test is fully corrected in post-test
Partial Change (PaC)	Some aspects of the misconception are corrected, but others remain
No Change (NoC)	The misconception remains the same before and after instruction
New Misconception (NeM)	A new misconception appears in the post-test that was not present in the pre-test

RESULTS AND DISCUSSION

Understanding momentum and impulse is crucial for students studying physics, as these concepts are fundamental in explaining various physical phenomena, from collisions in mechanics to applications in sports and engineering. However, research has consistently shown that many students struggle with these concepts, often developing misconceptions (MC) that persist despite traditional instruction. Addressing these misconceptions requires innovative teaching strategies that go beyond rote memorization and instead promote deep conceptual understanding.

In this study, the T-MORE model was implemented using a technology-enhanced approach to help students overcome misconceptions about momentum and impulse. To enhance the relevance and clarity of technology integration, the T-MORE model incorporated various digital tools, including PhET simulations, videos, and AI-assisted reflection platforms. Screenshots of the PhET simulations and videos used are presented in Figures 3 (Source: https://phet.colorado.edu/sims/html/collision-lab/latest/collision-lab_all.html) and Figure 4 (Source: https://www.youtube.com/watch?v=-kP87TYH-zg) to illustrate how these technologies were utilized.

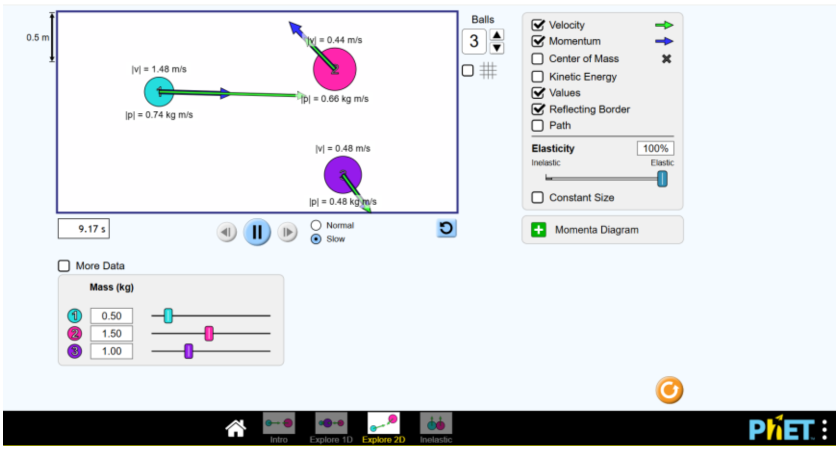

Figure 3. PhET Simulations about Collision

Figure 4. Illustration of the Application of Momentum in Daily Life

The effectiveness of this intervention was assessed through the Four-Tier Momentum and Impulse Misconception Diagnostic Test (FT-MIMDT), which categorizes students' understanding into Scientific Conception (SC), Misconception (MC), and No Conception (NC). The results of the pre-test and post-test are shown in Figure 5.

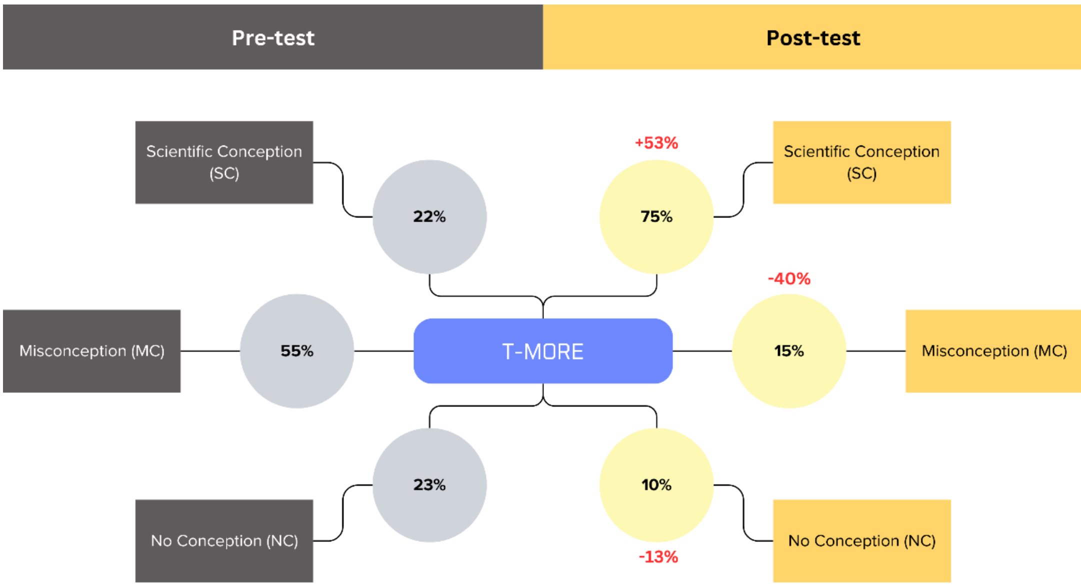

Figure 5. The Results of the Pre-Test and Post-Test after the T-MORE Intervention

As illustrated in Figure 5, the proportion of students classified as having MC decreased significantly from 55% to 15%, while those categorized as SC increased from 22% to 75%. Additionally, the NC category also declined from 23% to 10%, indicating that students not only corrected their misconceptions but also developed a more structured and scientifically accurate understanding. These findings suggest that the T-MORE model is effective in fostering conceptual change and reducing the prevalence of misconceptions. In addition to the technology integration, the role of the teacher or instructor was critical in guiding students throughout the learning process. During the implementation of T-MORE, teachers facilitated student engagement by prompting predictions before simulations, encouraging explanations during simulations, and guiding reflections afterward. This scaffolding approach ensured that students did not merely observe simulations passively but actively engaged with the conceptual content. Prior research has shown that instructor guidance enhances the effectiveness of technology-based learning environments (Geng et al., 2019; Wu et al., 2022).

To statistically validate these findings, a McNemar test was conducted to assess whether there was a significant change in students' conceptual understanding before and after the intervention. The analysis yielded a Chi-Square value of 234.102 ($p < 0.001$) (Table 5), indicating a highly significant shift in students' understanding. This result provides strong statistical evidence that the instructional approach effectively influenced students' conceptual development, rejecting the null hypothesis, which assumes that no meaningful change occurred. The significant p-value further suggests that the probability of this conceptual change occurring by chance is extremely low, thereby affirming the effectiveness of the T-MORE model in reducing misconceptions and fostering a scientific understanding of momentum and impulse.

Table 5. Result of McNemar Test

Test Statistics[a]

	Pretest & Posttest
N	308
Chi-Square[b]	234.102
Asymp. Sig.	.000

a. McNemar Test
b. Continuity Corrected

Beyond statistical significance, the effect size was calculated using Cohen's, yielding a value of 0.75 (95% CI), indicating a medium effect size based on standard benchmarks. This suggests that the intervention had a meaningful impact on reducing misconceptions. The confidence interval further confirms the robustness of the observed effect, reinforcing that the probability of this conceptual change occurring by chance is extremely low. Then, the magnitude of conceptual change was assessed using the Reduction of Misconception Quantity (RMQ) metric, which quantifies the extent to which misconceptions decreased throughout the instructional process. The RMQ value was calculated at 88.89%, placing it within the high reduction category. This result demonstrates that the T-MORE model successfully addressed and corrected misconceptions for the majority of students, emphasizing its potential as an instructional strategy to remediate persistent misconceptions in physics learning.

Besides the numerical representation of misconception reduction, it is essential to examine how students' conceptual understanding evolved qualitatively. Analyzing the nature of these changes provides deeper insights into how students reconstructed their reasoning and the specific conceptual hurdles they overcame. Table 6 presents examples of conceptual change categories observed in students' responses before and after instruction.

Table 6. Examples of Conceptual Change Categories

Category	Students	Questions	Pre-Test	Post-Test	Conceptual Change Description
Complete Change (CoC)	S3, S8, S11, S14	Q5	Momentum is lost after a collision if the objects stop moving. (MC)	Momentum is always conserved in a closed system, even if objects stop moving. (SC)	Initially misunderstood momentum conservation but corrected it after instruction.
	S2, S6, S10	Q7	Impulse only depends on the force applied, not on the time interval. (MC)	Impulse is the product of force and time; longer contact time reduces force impact. (SC)	Fully understood the impulse-momentum theorem after intervention.
	S4, S9, S16, S18, S20	Q9	Heavier objects always have greater momentum, regardless of velocity. (MC)	Momentum depends on both mass and velocity, so a lighter object can have greater momentum if its velocity is high. (SC)	Initially believed mass alone determined momentum but corrected it post-instruction.
Partial Change (PaC)	S5, S13	Q4	The coefficient of restitution determines how fast an object moves after a collision. (MC)	The coefficient of restitution measures how much velocity is retained, but I'm unsure how to calculate it. (NC)	Corrected the definition but struggled with its application.
	S1, S7, S15, S17	Q8	Elastic collisions always increase	Momentum is conserved, but	Improved understanding

Category	Students	Questions	Pre-Test	Post-Test	Conceptual Change Description
			kinetic energy. (MC)	I'm still unsure if kinetic energy always stays the same. (NC)	but retained some uncertainty.
	S6, S11	Q2	Momentum is proportional to mass and velocity. (NC)	Momentum is conserved, but they do not understand how direction affects it. (NC)	The student refined their understanding but lacked confidence in applying vector concepts.
No Change (NoC)	S10, S12, S18, S19	Q3	Momentum depends on both mass and velocity. A lighter object moving at high speed can have greater momentum than a heavier object moving slowly. (SC)	Momentum is the product of mass and velocity (p = mv). Two objects with different masses can have the same momentum if the lighter object moves faster. (SC)	Did not change their misconception despite instruction.
	S7, S14	Q9	Objects in a collision stop moving because their momentum disappears. (MC)	Objects in a collision stop moving because their momentum disappears. (MC)	Still misunderstood momentum conservation.
	S4, S13, S20	Q6	Impulse is just another term for force. (NC)	Impulse is just another term for force. (NC)	No conceptual progress; impulse-momentum relationship remains misunderstood.
New Misconception (NeM)	S9, S15	Q6	Impulse depends on force and time. (SC)	Impulse depends only on the speed of an object before impact. (MC)	Developed a new misconception about impulse after instruction.
	S11	Q2	Momentum is proportional to mass and velocity. (SC)	Momentum can exist even without motion as long as mass is present. (MC)	Incorrectly reinterpreted momentum after learning new concepts.

The results indicate that while the Technology-Integrated MORE Model (T-MORE) significantly increased the percentage of students achieving Scientific Conception (SC) and reduced misconceptions, not all students fully transitioned to correct scientific understanding. Some remained in the No Conception (NC) or even Misconception (MC) categories after instruction. This outcome aligns with previous research suggesting that misconceptions in physics, particularly in abstract topics like momentum and impulse, are highly resistant to change (Bani-Salameh, 2017; Fratiwi et al., 2024; Samsudin et al., 2016; Suhandi et al., 2017; Syaharudin et al., 2015). Conceptual change is not simply a process of replacing incorrect knowledge with correct explanations; instead, it requires restructuring mental models, which can be slow and complex (Disessa, 2017). Many students enter physics courses with intuitive beliefs that conflict with formal scientific principles, making it difficult to integrate new knowledge effectively. For example, some students continued to believe that momentum is solely determined by mass, despite PhET simulations that explicitly demonstrated how both mass and velocity contribute to momentum. This persistence suggests that while the T-MORE model successfully introduced conceptual conflicts, it may not have provided enough reinforcement for all students to completely overcome their misconceptions.

Beyond cognitive restructuring challenges, another factor influencing the variation in conceptual change was the depth of instructional engagement and the extent of contextual reinforcement, as students tend to need more time and diverse contexts to overcome their misconceptions due to the stability of their prior knowledge, the complexity of abstract physics concepts, and the role of metacognitive awareness in learning. The T-MORE model integrates videos, PhET simulations, and AI-assisted reflection to promote active learning; however, research suggests that students require multiple, varied encounters with their misconceptions across different scenarios to facilitate deeper conceptual shifts (Luneta, 2015; Qian & Lehman, 2017; Üce & Ceyhan, 2019). While the intervention was designed to be interactive, some students may have engaged only at a surface level, passively observing simulations without critically analyzing their misconceptions, which prior studies have shown to be less effective than actively predicting, testing, and explaining reasoning during simulations (Wang et al., 2015). This explains why some students transitioned from MC to NC rather than fully achieving SC, as they may have realized inconsistencies in their prior understanding but lacked sufficient reinforcement, contextual variation, or metacognitive prompting to confidently adopt the scientifically accurate explanation.

Another important factor affecting conceptual change is the complexity of the concepts themselves. The topics of momentum conservation, impulse-momentum relationships, and collision dynamics involve vector quantities, which have been consistently identified as areas where students struggle (Marshman & Singh, 2015). Even with visual and interactive learning tools, students often find it difficult to conceptualize vector addition, direction changes after collisions, and the transfer of momentum in different frames of reference. Some students in this study, particularly those in the PaC category, demonstrated a partial understanding of momentum conservation but still had difficulty applying it to real-world cases. This suggests that additional instructional strategies, such as collaborative problem-solving discussions and hands-on experiments, may be needed to reinforce vector-based reasoning and further support conceptual change.

The findings also highlight the role of student motivation and self-regulated learning in achieving conceptual understanding. Research has shown that students who actively engage in metacognitive reflection tend to show better learning outcomes (Bae & Kwon, 2021; Chen et al., 2019; Marantika, 2021). The T-MORE model incorporates AI-assisted reflection to facilitate self-assessment and conceptual reasoning, yet its effectiveness depends on how students interact with it. Some students may have used the AI tutor for superficial validation rather than as a tool for deep conceptual reflection, limiting its impact. Additionally, students with low intrinsic motivation or a preference for rote learning may have struggled to engage in the inquiry-driven approach of T-MORE, leading to slower conceptual progress. This aligns with prior research showing that conceptual change is more likely when students take an active role in questioning their misconceptions rather than relying solely on external explanations (Lombardi et al., 2016; Loyens et al., 2015; Wade-jaimes, 2018).

Although the T-MORE model demonstrated effectiveness in enhancing students' conceptual understanding, it is important to compare its efficacy with other instructional approaches. Previous studies have explored various methods for addressing misconceptions, such as Conceptual Change Texts (CCT) (Özyurt, 2015; Samsudin et al., 2019; Suhandi et al., 2017; Syuhendri, 2017; Yumuşak et al., 2015) and Predict-Observe-Explain (POE) strategies (Baydere, 2021; Cinici & Demir, 2013;

Jasdilla et al., 2019; Latifah et al., 2019; Samsudin et al., 2021). In comparison, T-MORE's technology integration potentially provides a more interactive and multimodal learning experience. However, a direct comparison with these approaches was not conducted in this study, which presents a limitation.

Overall, the findings underscore that while the Technology-Integrated MORE Model (T-MORE) effectively reduces misconceptions and enhances scientific conceptions, conceptual change remains a gradual and multifaceted process influenced by cognitive, instructional, and motivational factors, and to further refine T-MORE, future implementations could incorporate adaptive learning pathways, where students receive personalized scaffolding based on their misconception profiles, integrate real-world experimental activities alongside digital simulations to strengthen conceptual understanding by bridging virtual and physical learning experiences, and expand the AI-assisted feedback system to include dynamic prompts and misconception-specific explanations for more targeted interventions, ensuring students not only recognize but also correct their misunderstandings effectively.

LIMITATIONS

While this study provides valuable insights into the effectiveness of the T-MORE model, several limitations must be acknowledged. First, the study was conducted with a relatively small sample size of first-semester undergraduate students from a single university, which may limit the generalizability of the findings. Future research should consider expanding the sample size and including students from diverse educational backgrounds to explore broader applicability. Second, the intervention was implemented over a relatively short period, and the long-term retention of conceptual change was not assessed. Longitudinal studies could provide further insights into the lasting impact of technology-integrated interventions. Additionally, the study primarily relied on self-reported confidence levels in the four-tier diagnostic test, which may introduce potential biases. Incorporating additional assessment tools, such as think-aloud protocols or interviews, could further validate students' conceptual understanding and reasoning processes.

CONCLUSION

This study demonstrates that the Technology-Integrated MORE Model (T-MORE) is an effective instructional approach for remediating misconceptions and fostering deep learning in the context of momentum and impulse. Through a combination of technology-enhanced inquiry, structured reflection, and targeted conceptual interventions, students exhibited significant improvements in their conceptual understanding. The integration of videos, PhET simulations, and AI-assisted reflection tools played a crucial role in helping students transition from intuitive, everyday reasoning to more scientifically accurate conceptions. The findings indicate that conceptual change is not merely a process of acquiring new knowledge but requires restructuring of mental models, which can be effectively supported through technology-driven instruction. Furthermore, the combination of quantitative and qualitative analyses provided a comprehensive understanding of how students' misconceptions evolved, revealing that while many successfully corrected their misconceptions, some required additional reinforcement.

Despite the overall success of the T-MORE model, certain misconceptions persisted, highlighting the complexity of conceptual change and the need for sustained instructional support. Some students struggled with abstract representations of momentum and impulse, suggesting that additional scaffolding, collaborative discussions, and extended reflection opportunities could further enhance learning outcomes. To optimize the effectiveness of T-MORE, future implementations should consider incorporating adaptive formative assessments and personalized feedback mechanisms to support students at different levels of conceptual understanding. To strengthen the evidence for T-MORE's effectiveness, future research should employ a comparative experimental design that directly contrasts T-MORE with traditional instructional methods, such as lecture-based teaching, Conceptual Change Texts (CCTs), or Interactive Lecture Demonstrations (ILDs). This would help determine the relative impact of T-MORE in facilitating conceptual change. Additionally, incorporating pre-and post-test measures with control and experimental groups could provide more robust insights into the model's efficacy. Future studies should also explore how adaptive formative assessments and personalized feedback can be systematically integrated into T-MORE to enhance its adaptability to different learner needs. As physics misconceptions remain a major barrier to student learning, integrating technology-driven inquiry, structured reflection, and interactive feedback presents a promising pathway for fostering deeper engagement and a more meaningful understanding of fundamental physics concepts

AUTHOR CONTRIBUTIONS

RA led the research design, execution, data collection, statistical analysis, and initial drafting of the manuscript. ASH and ASM contributed to the conceptualization of the study, supervised the research process, and provided critical revisions to the content of the manuscript. ES and ASW provided methodological insights and contributed to the literature review and theoretical framework of the study. NJF participated in the interpretation of results, contributed to the discussion section, and assisted in refining the manuscript's narrative for coherence and flow.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Indonesian Education Scholarship (Beasiswa Pendidikan Indonesia - BPI). Special thanks are extended to the experts who provided valuable feedback on the development of the four-tier diagnostic test and all students who participated in this study. The author admits that he couldn't have done everything without help and guidance from Mrs. Jamilah Kleb as mom and Mr. Salmin Kleb as uncle.

REFERENCES

Adimayuda, R., Aminudin, A. H., Kaniawati, I., Suhendi, E., & Samsudin, A. (2020). A multitier open-ended momentum and impulse (MOMI) instrument: Developing and assessing quality of conception of 11th grade sundanese students with rasch analysis. *International Journal of Scientific and Technology Research*, *9*(2), 4799–4804.

Amalia, S. A., Suhendi, E., Kaniawati, I., Samsudin, A., Fratiwi, N. J., Hidayat, S. R., Zulfikar, A., Sholihat, F. N., Jubaedah, D. S., Setyadin, A. H., Purwanto, M. G., Muhaimin, M. H., Bhakti, S. S., & Afif, N. F. (2019). Diagnosis of student's misconception on momentum and impulse trough inquiry learning with computer simulation (ILCS). *Journal of Physics: Conference Series*, *1204*(1). https://doi.org/10.1088/1742-6596/1204/1/012073

Bae, H., & Kwon, K. (2021). Developing metacognitive skills through class activities: What makes students use metacognitive skills? *Educational Studies*, *47*(4), 456–471. https://doi.org/10.1080/03055698.2019.1707068

Bakker, A., Cai, J., English, L., Kaiser, G., Mesa, V., & Van Dooren, W. (2019). Beyond small, medium, or large: Points of consideration when interpreting effect sizes. *Educational Studies in Mathematics, 102*, 1–8. https://doi.org/10.1007/s10649-019-09908-4

Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, *17*(2). https://doi.org/10.1103/PhysRevPhysEducRes.17.023108

Bani-Salameh, H. N. (2017). How persistent are the misconceptions about force and motion held by college students? *Physics Education*, *52*(1). https://doi.org/10.1088/1361-6552/52/1/014003

Baydere, F. K. (2021). Effects of a context-based approach with prediction-observation-explanation on conceptual understanding of the states of matter, heat and temperature. *Chemistry Education Research and Practice*, *22*(3), 640–652. https://doi.org/10.1039/D0RP00348D

Bessas, N., Tzanaki, E., Vavougios, D., & Plagianakos, V. P. (2024). Diagnosing students' misconception in Hydrostatic Pressure through a 4-tier test. *Heliyon*, *10*(23). https://doi.org/10.1016/j.heliyon.2024.e40425

Brundage, M. J., Maries, A., & Singh, C. (2023). Using the Energy and Momentum Conceptual Survey to investigate progression in student understanding from introductory to advanced levels. *Physical Review Physics Education Research*, *19*(2). https://doi.org/10.1103/PhysRevPhysEducRes.19.020132

Chen, M. R. A., Hwang, G. J., & Chang, Y. Y. (2019). A reflective thinking-promoting approach to enhancing graduate students' flipped learning engagement, participation behaviors, reflective thinking and project learning outcomes. *British Journal of Educational Technology*, *50*(5), 2288–2307. https://doi.org/10.1111/bjet.12823

Cinici, A., & Demir, Y. (2013). Teaching through Cooperative POE Tasks: A path to conceptual change. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *86*(1), 1–10. https://doi.org/10.1080/00098655.2012.712557

Dalila, A. A., Rahmah, S., Liliawati, W., & Kaniawati, I. (2022). Effect of differentiated learning in problem based learning on cognitive learning outcomes of high school students. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2116–2122. https://doi.org/10.29303/jppipa.v8i4.1839

Demir, S. B. (2018). A convergent parallel mixed-methods study of controversial issues in social studies classes: A clash of ideologies. *Kuram ve Uygulamada Egitim Bilimleri*, *18*(1), 119–149. https://doi.org/10.12738/estp.2018.1.0298

Diani, R., Latifah, S., Anggraeni, Y. M., & Fujiani, D. (2018). Physics learning based on virtual laboratory to remediate misconception in fluid material. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *3*(2), 167. https://doi.org/10.24042/tadris.v3i2.3321

Disessa, A. A. (2017). Conceptual change in a microcosm: Comparative learning analysis of a learning event. *Human Development*, *60*(1), 1–37. https://doi.org/10.1159/000469693

Estipular, M. K. L., & Roleda, L. S. (2018). The use of interactive lecture demonstration with interactive simulation in enhancing students ' conceptual understanding in Physics. *DLSU Research Congress 2018*.

Fratiwi, N. J., Suhandi, A., Feranie, S., & Linuwih, S. (2024). Reducing alternative conception of action-reaction forces : The impact of e-rebuttal texts after learning and over time. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *9*(2), 321–334. https://doi.org/10.24042/tadris.v9i2.22995

Geng, S., Law, K. M. Y., & Niu, B. (2019). Investigating self-directed learning and technology readiness in blending learning environment. *International Journal of Educational Technology in Higher Education*, *16*(17), 1–22. https://doi.org/10.1186/s41239-019-0147-0

Ghadiri, Z., Norouzi, D., & Fardanesh, H. (2016). Investigation of the effect of computer simulation-based learning based on constructivism in removing Physics misconceptions. *Interdisciplinary Journal of Virtual Learning in Medical Sciences*, *6*(4). https://doi.org/10.5812/ijvlms.11997

Jasdilla, L., Fitria, Y., & Sopandi, W. (2019). Predict Observe Explain (POE) strategy toward mental model of primary students. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1157/2/022043

Kaniawati, I., Danawan, A., Suyana, I., Samsudin, A., & Suhendi, E. (2021). Implementation of interactive conceptual instruction (ICI) with computer simulation: Impact of students' misconceptions on momentum and impulse material. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *10*(1), 1–17. https://doi.org/10.24042/jipfalbiruni.v10i1.8375

Latifah, S., Irwandani, I., Saregar, A., Diani, R., Fiani, O., Widayanti, W., & Deta, U. A. (2019). How the Predict-Observe-Explain (POE) learning strategy remediates students' misconception on Temperature and Heat materials? *Journal of Physics: Conference Series*, 1–6. https://doi.org/10.1088/1742-6596/1171/1/012051

Lombardi, D., Nussbaum, E. M., & Sinatra, G. M. (2016). Plausibility judgments in conceptual change and epistemic cognition. *Educational Psychologist*, *51*(1), 35–56. https://doi.org/10.1080/00461520.2015.1113134

Loyens, S. M. M., Jones, S. H., Mikkers, J., & van Gog, T. (2015). Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, *38*, 34–42. https://doi.org/10.1016/j.learninstruc.2015.03.002

Luneta, K. (2015). Understanding students' misconceptions: An analysis of final grade 12 examination questions in geometry. *Pythagoras*, *36*(1). https://doi.org/10.4102/pythagoras.v36i1.261

Marantika, J. E. R. (2021). Metacognitive ability and autonomous learning strategy in improving learning outcomes. *Journal of Education and Learning (EduLearn)*, *15*(1), 88–96. https://doi.org/10.11591/edulearn.v15i1.17392

Maries, A., Brundage, M. J., & Singh, C. (2023). Upper-level students' conceptual understanding of energy and momentum. *Physics Education Research Conference Proceedings*, 205–210. https://doi.org/10.1119/perc.2023.pr.Maries

Marshman, E., & Singh, C. (2015). Framework for understanding the patterns of student difficulties in quantum mechanics. *Physical Review Special Topics - Physics Education Research*, *11*(2). https://doi.org/10.1103/PhysRevSTPER.11.020119

Minichiello, A., Hood, J. R., & Harkness, D. S. (2018). Bringing user experience design to bear on STEM education: A narrative literature review. *Journal for STEM Education Research*, *1*(1–2), 7–33. https://doi.org/10.1007/s41979-018-0005-3

Mufit, F. (2018). The study of misconceptions on motion's concept and remediate using real experiment video analysis. *Asean Comparative Education Research Network Conference*, 1–7. https://doi.org/10.31227/osf.io/2vjrp

Ndumanya, E., Ramnarain, U., & Wu, H. K. (2021). An analysis of selected south african grade 12 physical sciences textbooks for the inclusion of the NGSS science practices. *Canadian Journal of Science, Mathematics and Technology Education*, *21*(3), 539–552. https://doi.org/10.1007/s42330-021-00169-z

Nyoman, N., Putu, S., Nisrina, N., & Mataram, U. (2024). The role of artificial intelligence (AI) in transforming physics education: A narrative review. *Lensa: Jurnal Kependidikan Fisika*, *12*(2), 212–228. https://doi.org/10.33394/j-lkf.v12i2.13523

Özyurt, Ö. (2015). Examining the critical thinking dispositions and the problem solving skills of computer engineering students. *Eurasia Journal of Mathematics*, *11*(2), 353–361. https://doi.org/10.12973/eurasia.2015.1342a

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Qian, Y., & Lehman, J. (2017). Students' misconceptions and other difficulties in introductory programming: A literature review. *ACM Transactions on Computing Education*, *18*(1), 1–24. https://doi.org/10.1145/3077618

Rivaldo, L., Taqwa, M. R. A., Zainuddin, A., & Faizah, R. (2020). Analysis of students' difficulties about work and energy. *Journal of Physics: Conference Series*, *1567*(3). https://doi.org/10.1088/1742-6596/1567/3/032088

Sakinah, N., Amalia, I. F., & Adimayuda, R. (2023). Identifying senior high school students' misconception on the momentum and impulse concepts uses three-tier diagnostic test. *Research in Physics Education*, *2*(1), 18–25. https://doi.org/10.31980/ripe.v2i1.2377

Samsudin, A., Aminudin, A. H., Novia, H., & Suhandi, A. (2023). Identifying javanese students ' conceptions on fluid pressure with wright map analysis of Rasch. *Journal of Natural Science and Integration*, *6*(2), 173–185. https://doi.org/10.24014/jnsi.v6i2.21822

Samsudin, A., Rusdiana, D., Efendi, R., Fratiwi, N. J., Aminudin, A. H., & Adimayuda, R. (2021). Development of Predict-Observe-Explain (POE) strategy assisted by rebuttal texts on newton's law material with rasch analysis. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *6*(1), 103–115. https://doi.org/10.24042/tadris.v6i1.7641

Samsudin, A., Suhandi, A., Rusdiana, D., Kaniawati, I., & Coştu, B. (2016). Investigating the effectiveness of an active learning based-interactive conceptual instruction (ALBICI) on electric field concept. *Asia-Pacific Forum on Science Learning and Teaching*, *17*(1), 1–41.

Samsudin, A., Suhandi, A., Rusdiana, D., Kaniawati, I., Fratiwi, N. J., Zulfikar, A., Muhaemin, M. H., Hermita, N., Mansur, Wibowo, F. C., Supriyatman, Malik, A., & Costu, B. (2019). Optimizing students' conceptual understanding on electricity and magnetism through cognitive conflict-based multimode teaching (CC-BMT). *Journal of Physics: Conference Series*, *1204*(1). https://doi.org/10.1088/1742-6596/1204/1/012027

Sari, P. M., Herlina, K., & Abdurrahman, A. (2022). Online learning with multi-representation worksheets for oral and written communication skills on light reflecting material. *Online Learning in Educational Research, 2*(1), 49-56. https://doi.org/10.58524/oler.v2i1.122

Schoormann, T., Möller, F., Di Maria, M., & Große, N. (2023). Guiding design principle projects: a canvas for young design science researchers. *Journal of Information Systems Education*, *34*(3), 307–325.

Setiani, A., Firmansyah, D., & Ramadhani, C. I. (2023). Analysis of momentum and impulse misconceptions of college students using four-tier diagnostic tests. *International Journal of Education and Teaching Zone*, *2*(3), 349–359. https://doi.org/10.57092/ijetz.v2i3.146

Stefanou, M., Stylos, G., Georgopoulos, K., & Kotsis, K. T. (2024). Primary preservice teachers' misconceptions and reasoning of thermal concepts in everyday contexts. *International Journal of Learning in Higher Education*, *31*(1), 127–157. https://doi.org/10.18848/2327-7955/CGP/v31i01/127-157

Suhandi, A., Hermita, N., Samsudin, A., Maftuh, B., & Coştu, B. (2017). Effectiveness of visual multimedia supported conceptual change texts on overcoming students' misconception about boiling concept. *Turkish Online Journal of Educational Technology*, 1012–1022.

Surya, J., Suryani, Y., & Saregar, A. (2022). Physics vlogs learning videos on parabolic motion on youtube channels based on scientific approach. *Online Learning in Educational Research, 2*(1), 19-29. https://doi.org/10.58524/oler.v2i1.108

Syaharudin, N., Daud, N., Mustamam, M., Karim, A., Wan, S., Wan, N., Nurulhuda, H. &, & Rahman, A. (2015). Misconception and difficulties in introductory physics among high school and university students : An Overview in Mechanics. *EDUCATUM-Journal of Science, Mathematics and Technology*, *2*(1), 34–47.

Syuhendri, S. (2017). A learning process based on conceptual change approach to foster conceptual change in newtonian mechanics. *Journal of Baltic Science Education*, *16*(2), 228–240. https://doi.org/10.33225/jbse/17.16.228

Tong, D., Liu, J., Sun, Y., Liu, Q., Zhang, X., Pan, S., & Bao, L. (2023). Assessment of student knowledge integration in learning work and mechanical energy. *Physical Review Physics Education Research*, *19*(1). https://doi.org/10.1103/PhysRevPhysEducRes.19.010127

Triyani, G., Danawan, A., Suyana, I., & Kaniawati, I. (2019). An investigation of students' misconceptions about momentum and impulse through interactive conceptual Instruction (ICI) with computer simulation. *Journal of Physics: Conference Series*, *1280*(5). https://doi.org/10.1088/1742-6596/1280/5/052008

Üce, M., & Ceyhan, İ. (2019). Misconception in Chemistry education and practices to eliminate them: Literature analysis. *Journal of Education and Training Studies*, *7*(3), 202. https://doi.org/10.11114/jets.v7i3.3990

Wade-jaimes, K. (2018). *Modeling strategies enhanced by metacognitive tools in high school physics to support student conceptual trajectories and understanding of electricity*. *April*, 1–33. https://doi.org/10.1002/sce.21444

Wang, X., Yang, D., Wen, M., Koedinger, K., & Rosé, C. P. (2015). Investigating how student's cognitive behavior in MOOC discussion forums affect learning gains. *Proceedings of the 8th International Conference on Educational Data Mining*, 226–233.

Wu, I. L., Hsieh, P. J., & Wu, S. M. (2022). Developing effective e-learning environments through e-learning use mediating technology affordance and constructivist learning aspects for performance impacts: Moderator of learner involvement. *Internet and Higher Education*, *55*. https://doi.org/10.1016/j.iheduc.2022.100871

Yumuşak, A., Maraş, I., & Şahin, M. (2015). Effects of computer-assisted instruction with conceptual change texts on removing the misconceptions of radioactivity. *Journal for the Education of Gifted Young Scientists*, *3*(2), 23–50. https://doi.org/10.17478/JEGYS.2015214277