Developing e-refutation texts and dyads peer argumentation (eRT-DPA) to overcome momentum and impulse misconceptions

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Abstract
This study aimed to develop electronic Refutation Texts and Dyads Peer Argumentation (eRT-DPA) as a learning resource for addressing high school students' misconceptions concerning momentum and impulse. The study employed the ADDIE development model, which comprised the Analysis, Design, Development, Implementation, and Evaluation phases. The implementation involved 29 eleventh-grade students (13 male and 16 female students, ages 16 to 17 years) from a senior high school in Indramayu, Indonesia. The developed materials were evaluated by three experts using the Learning Object Review Instrument, while students' conceptions were assessed using an 11-item four-tier diagnostic test and analyzed through conception-category percentages and Rasch Wright maps. Expert validation produced an average score of 4.30, indicating that eRT-DPA was feasible for implementation. Following the intervention, the proportion of responses classified as misconceptions decreased from 25% to 20%, while Partial Understanding increased from 41% to 46% and Sound Understanding increased from 22% to 23%. These descriptive changes suggest that eRT-DPA has potential as a structured conceptual intervention, although they should not be interpreted as definitive evidence of effectiveness. For physics teachers, eRT-DPA provides a practical framework for linking diagnostic assessment with targeted remediation. Teachers can identify specific misconceptions, present explicit refutations and scientific explanations, and engage students in structured paired discussions and reflection to reconsider their initial conceptions.

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1. Introduction

A sound conceptual understanding of momentum and impulse is essential in physics because these concepts connect mass, velocity, force, time, and changes in motion and underpin the analysis of collisions, explosions, and conservation processes. Learning these concepts requires more than recalling mathematical formulas. Students must coordinate several physical quantities, distinguish momentum from related concepts such as force and kinetic energy, and reason about how an interaction occurring over a time interval changes an object's motion. These proportional and relational demands make momentum and impulse an important context for developing scientific reasoning and evidence-based thinking (Bao & Koenig, 2019; Jamil et al., 2024; Osborne, 2013). Moreover, because these concepts provide a foundation for subsequent learning about collisions and conservation laws, unresolved difficulties may hinder students' broader understanding of mechanics.

The need for systematic investigation is further reinforced by the persistence and diversity of misconceptions reported even after students have received formal instruction. Previous studies have shown that students may regard momentum as being determined only by mass while overlooking velocity, assume that a larger collision force necessarily produces a larger impulse without

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considering contact time, or infer that momentum is not conserved when velocity or kinetic energy changes during a collision (Adimayuda et al., 2020; Amalia et al., 2019; Sakinah et al., 2023; Sarıoğlan & Küçüközer, 2014; Setiani et al., 2023). These conceptions should not be interpreted merely as isolated mistakes, calculation errors, or failures to recall formulas. Rather, they represent relatively stable alternative conceptual frameworks through which students interpret everyday physical events involving motion, force, and collisions. Because these frameworks may appear internally plausible to students and become embedded in their existing cognitive structures, they often persist even after formal instruction and are resistant to conventional explanations (Disessa, 2017; Tulis, 2022). Consequently, momentum and impulse warrant targeted investigation because they reveal persistent conflicts between students' intuitive reasoning and the coordinated scientific relationships required to explain physical interactions.

Given these persistent and topic-specific misconceptions, instructional strategies are needed that do not merely present correct formulas but explicitly confront and reconstruct the underlying conceptions. One strategy developed to facilitate this process is the use of refutation texts (Mufida et al., 2023; Muliyani, 2018; Samsudin et al., 2021; Susilowati et al., 2025; Taylor & Kowalski, 2023). This approach offers the presentation of scientific information that explicitly refutes students' false beliefs by demonstrating why they are incorrect, while simultaneously introducing correct scientific explanations (Ferrero et al., 2020; Kendeou et al., 2014; van Loon et al., 2015). Refutation texts are typically structured in three main sections, a statement of a common misconception, a direct refutation of the misconception, and a scientific explanation supported by logic and evidence. In numerous studies, refutation texts have been shown to improve students' conceptual understanding and reduce misconceptions, particularly when used for complex and counterintuitive topics (Lassonde et al., 2016; Mufida et al., 2023; Zengilowski et al., 2021). However, the effectiveness of this approach is inconsistent, particularly when not accompanied by further cognitive activities that allow students to process and reconstruct their knowledge in depth (Asterhan & Resnick, 2020).

In the context of physics learning, conceptual change requires not only exposure to correct information but also active student engagement in reflecting on, comparing, and evaluating conflicting ideas. One strategy that supports this process is dyad peer argumentation, a pair-based discussion that allows students to express opinions, test arguments, and compare their understandings in a collaborative yet critical setting (Asterhan & Resnick, 2020). Through this social argumentation process, students are encouraged to evaluate their own and their partner's misconceptions and reformulate more coherent scientific understandings. Research shows that this type of discussion is effective in stimulating conceptual shift (Li et al., 2023), especially when accompanied by the exchange of evidence-based arguments and the use of explicit scientific language.

However, the integration of refutation texts and peer argumentation dyads has not been widely empirically studied in a single, integrated approach. Previous research tends to separate the two strategies: some focus on the effectiveness of refutation texts in individual contexts, while others examine the contribution of peer argumentation without explicitly presenting misconceptions (Asterhan & Dotan, 2018). Even an experimental study by Asterhan and Resnick (2020) showed that pair argumentation after reading refutation texts does not always provide significant additional effects, unless the quality of the discussion meets certain characteristics such as symmetry of contributions and discussion of core principles. This confirms that the effectiveness of the combination of the two is strongly influenced by task design, the quality of social interactions, and learner characteristics.

To fill this gap, it is necessary to develop a learning approach that systematically combines the advantages of refutation texts and the potential of argumentative discussion in the context of physics learning. By integrating exposure to scientific information that refutes misconceptions and discussion activities among students that enable them to rebuild their understanding collaboratively, it is hoped that the process of conceptual change can occur more deeply and sustainably. Furthermore, the use of digital media in the form of electronic Refutation Texts (e-RT) can provide flexibility in material delivery and facilitate student access to adaptive and interactive learning resources.

This study aims to develop an electronic Refutation Texts and Dyads Peer Argumentation (eRT-DPA) approach to address misconceptions in momentum and impulse concepts among high school students. This approach combines the presentation of refutation texts in electronic format with structured paired argumentative discussion activities. This innovation is designed to optimize the role of cognitive and social processes in conceptual change, through the use of educational technology and a dialogue-based approach. The use of e-RT allows students to access information independently and flexibly, while the dyads argumentation activities encourage cognitive and metacognitive elaboration through meaningful social interactions.

2. Method

This study uses the ADDIE model, which consists of five stages, namely analysis, design, development, implementation, and evaluation. In the analysis stage, student misconceptions were identified through two approaches, including a literature review of common misconceptions regarding the concepts of momentum and impulse, and a literature review of the theory of refutation texts and dyads-peer argumentation. Additionally, an initial diagnostic test, a four-tier test, was administered to eleventh-grade students in the 2024/2025 academic year. The results of this stage served as the basis for developing refutation text materials and designing discussion activities relevant to students' cognitive abilities. The design stage included the development of an initial draft of the eRT-DPA, which consisted of two main components, including electronic refutation texts containing common misconceptions, explicit rebuttals, and correct scientific explanations, and structured pair discussion activities (dyads-peer argumentation) to encourage exploration of scientific understanding and argumentation among students.

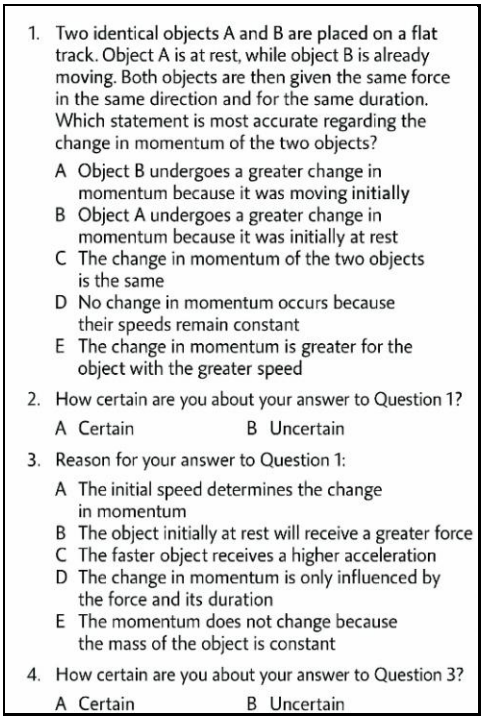
In the development stage, the eRT-DPA was developed digitally, in both interactive text formats and discussion worksheets. The resulting product was then validated by experts in the field of physics education consisting of two physics education lecturers and one physics teacher. The assessment was conducted using the Learning Object Review Instrument (LORI) version 1.5 (Marín et al., 2019), which includes nine assessment dimensions, which cover key dimensions such as content quality, alignment with learning objectives, feedback and adaptability, learner motivation, presentation design, interactivity, accessibility, reusability, and adherence to technical standards. Each dimension was assessed using a Likert scale of 1–5, with the final assessment categories listed in Table 1. Input from the validators was used to revise and refine the eRT-DPA before being piloted.

Table 1. Expert Validation Category Related to eRT-DPA

Average Score Range	Categories
4.51-5.00	Very Feasible
3.51-4.50	Feasible
2.51-3.50	Moderate
1.51-2.50	Not Feasible
1.00-1.50	Very Not Feasible

The implementation phase involved 29 eleventh-grade students (13 boys and 16 girls, aged 16-17) from a high school in Indramayu Regency, Indonesia, in the 2025/2026 academic year. Students participated in two learning sessions, which included independent reading of refutation texts using digital devices, followed by a week-long pair discussion to address misconceptions and strengthen conceptual understanding. All activities were facilitated by a physics teacher. The DPA activities were implemented as an instructional component of eRT-DPA, while the empirical evaluation focused on product feasibility and changes in students' conception categories; argumentation quality was not assessed as a separate learning outcome.

In the evaluation phase, students' conceptions were measured using a four-tier diagnostic test containing 11 questions on momentum and impulse. The four-tier diagnostic test, named Instruments of Four-tier Multi-representational on Momentum and Impulse (INFORMI), was validated using a Rasch model. The results indicated that the instrument met the requirement for construct validity (30%), and all items met the fit criteria, with Outfit MNSQ values ranging from 0.60 to 1.46. The item reliability reached 0.86, and Cronbach's alpha was 0.62. An example of a four-tier test is shown in Figure 1.



1. Two identical objects A and B are placed on a flat track. Object A is at rest, while object B is already moving. Both objects are then given the same force in the same direction and for the same duration. Which statement is most accurate regarding the change in momentum of the two objects?
   - A Object B undergoes a greater change in momentum because it was moving initially
   - B Object A undergoes a greater change in momentum because it was initially at rest
   - C The change in momentum of the two objects is the same
   - D No change in momentum occurs because their speeds remain constant
   - E The change in momentum is greater for the object with the greater speed
2. How certain are you about your answer to Question 1?
   - A Certain B Uncertain
3. Reason for your answer to Question 1:
   - A The initial speed determines the change in momentum
   - B The object initially at rest will receive a greater force
   - C The faster object receives a higher acceleration
   - D The change in momentum is only influenced by the force and its duration
   - E The momentum does not change because the mass of the object is constant
4. How certain are you about your answer to Question 3?
   - A Certain B Uncertain

Figure 1. Example of INFORMI

The four-tier diagnostic responses were classified by jointly considering the correctness of students' answers and reasons and their confidence in both responses. Tier 1 represented the selected answer, Tier 2 represented confidence in the answer, Tier 3 represented the selected reason, and Tier 4 represented confidence in the reason. This classification scheme was adapted from Fratiwi et al (2020). Sound Understanding (SU) was assigned only when both the answer and reason were correct and the student was certain about both. Misconception (MC) was assigned when both the answer and reason were incorrect and the student was certain about both, indicating that the incorrect conception was held with confidence. No Understanding (NU) referred to responses in which both the answer and reason were incorrect, but uncertainty was expressed in at least one of the confidence tiers. Partial Understanding (PU) included responses showing incomplete or inconsistent understanding, such as a correct answer accompanied by an incorrect reason, an incorrect answer accompanied by a correct reason, or correct responses accompanied by uncertainty. Responses with one or more incomplete tiers were classified as No Coding (NC). The complete classification rules are presented in Table 2.

Table 2. Students' Conception Categories Based on INFORMI

Conception Categories	Tier 1	Tier 2	Tier 3	Tier 4
Sound Understanding (SU)	Correct	Certain	Correct	Certain
Partial Understanding (PU)	Correct	Certain	Correct	Uncertain
	Correct	Uncertain	Correct	Certain
	Correct	Uncertain	Correct	Uncertain
	Correct	Certain	Incorrect	Certain
	Correct	Certain	Incorrect	Uncertain
	Correct	Uncertain	Incorrect	Certain
	Correct	Uncertain	Incorrect	Uncertain
	Incorrect	Certain	Correct	Certain
	Incorrect	Certain	Correct	Uncertain
	Incorrect	Uncertain	Correct	Certain
	Incorrect	Uncertain	Correct	Uncertain
No Understanding (NU)	Incorrect	Certain	Incorrect	Uncertain
	Incorrect	Uncertain	Incorrect	Certain
	Incorrect	Uncertain	Incorrect	Uncertain
Misconception (MC)	Incorrect	Certain	Incorrect	Certain
No Coding (NC)	Responses do not match one or more tiers (incomplete)			

(Fratiwi et al., 2020)

Each student's response to each item was coded according to the classification rules in Table 2. The percentage of each conception category was calculated by dividing the number of item responses classified in that category by the total number of coded item responses and multiplying the result by 100. The pre-test and post-test distributions were then compared descriptively to identify changes in Sound Understanding, Partial Understanding, No Understanding, and Misconception after the implementation of eRT-DPA. In addition, a Rasch person–item map, commonly referred to as a Wright map, was used to represent students' locations relative to item difficulty before and after the intervention.

3. Results and Discussion

This section presents the research results based on the stages in the ADDIE model, namely analysis, design, development, implementation, and evaluation. Each stage is explained to demonstrate how the electronic Refutation Texts and Dyads Peer Argumentation (eRT-DPA) approach was systematically developed and implemented to reduce student misconceptions on momentum and impulse concepts.

3.1. Analysis

In the analysis phase, student misconceptions were identified through two approaches, including a literature review and an initial diagnostic test in the form of a four-tier test for eleventh-grade students in the 2024/2025 academic year as many as 37 students. The literature review was conducted to identify the most common misconceptions surrounding the concepts of momentum and impulse. The literature review revealed several misconceptions that consistently emerged across various studies. First, many students confuse the concepts of force and impulse. Students tend to believe that collisions involving large forces automatically produce large impulses, without considering the duration of contact. This misconception ignores the definition of impulse as the product of force and time and often arises from students' tendency to associate violent collisions with large changes in momentum (Adianto & Rusli, 2021; Fang & Guo, 2023; Liu & Fang, 2016).

Second, there is a misunderstanding of the law of conservation of momentum during collisions. In perfectly elastic collisions, students often fail to understand that the total momentum of the system remains constant, even though the velocities of the objects change after the collision. Some students assume that changes in kinetic energy or velocity indicate that momentum is not conserved, even though the two laws (conservation of momentum and conservation of kinetic energy) are different principles. This error is reflected in previous studies (Ben-Abu, 2019; Singh & Rosengrant, 2016; Wong & Wong, 2022). Third, the literature also shows that students often understand momentum as dependent solely on an object's mass, without considering the role of velocity. As a result, students assert that heavier objects always have greater momentum, even if they move more slowly than lighter objects. This misconception contradicts the scientific definition of momentum as the product of mass and velocity (Amalia et al., 2019; Diyanahesa et al., 2017; Triyani et al., 2019).

As a complement, a four-tier diagnostic test was administered to students to obtain a snapshot of their actual understanding in the classroom. The results of this initial test indicated that the types of misconceptions found in the literature also emerged among the students who participated in the study. The percentage of misconceptions for each common misconception is shown in Table 3.

Table 3. Percentage of Misconceptions for Each Common Misconception about Momentum and Impulse

No.	Common Misconception	Percentage (%)
1	Momentum depends only on mass, not velocity.	51
2	Objects with equal momentum always travel the same distance, regardless of mass or speed.	16
3	Momentum becomes zero at the peak because velocity is zero.	22
4	Greater bounce means greater impulse, regardless of contact time or initial speed.	43
5	Both objects experience impulse in the same direction during a collision.	14
6	Larger force always results in larger impulse, ignoring time duration.	5
7	Time has no effect on impulse; only force matters.	19
8	Heavier object always has greater momentum, even if the lighter one moves faster.	43
9	If kinetic energy changes, then momentum must also change.	19
10	If object speeds change after collision, momentum is not conserved.	24
11	In inelastic collisions, both kinetic energy and momentum are lost.	16

These findings reinforce the urgency of developing learning media that explicitly target these misconceptions. Therefore, the results of this analysis phase serve as the primary basis for developing refutation text content and designing pair discussion activities that are relevant and contextual to students' learning needs. The eRT-DPA approach was developed for two concepts: the concept of momentum, which states that "many students assume that heavier objects always have greater momentum than lighter objects," and the concept of impulse, which states that "many students assume that ball A, made of rubber and bouncing after colliding with a wall, will experience a smaller impulse than ball B, which is made of plasticine and sticks to the wall without bouncing."

Furthermore, a literature review of refutation texts indicates that this approach has proven effective in helping students correct their misconceptions. Refutation texts combine the presentation of correct information with refutation of existing misconceptions, enabling students to more clearly understand why their views are incorrect and what the correct understanding is. Previous studies have shown that refutation texts are more effective than traditional expository texts because they explicitly challenge false beliefs and encourage students to think critically and reflectively (Asterhan & Resnick, 2020; Danielson et al., 2025).

To enhance the effectiveness of refutation texts, this approach can be combined with dyadic peer argumentation, which involves pair discussions between students to question and clarify their understanding of a concept. Dyadic peer argumentation fosters social interaction, allowing students to share understanding, defend their arguments, and collaboratively correct misconceptions. This approach serves to strengthen students' understanding because they can verify and confront their ideas with peers in the context of in-depth discussions. The combination of refutation texts and dyadic peer argumentation is believed to be more effective in addressing misconceptions in physics concepts, such as momentum and impulse, by providing space for students to reflect on and correct their understanding through critical argumentation. The eRT-DPA integration framework is shown in Figure 2.

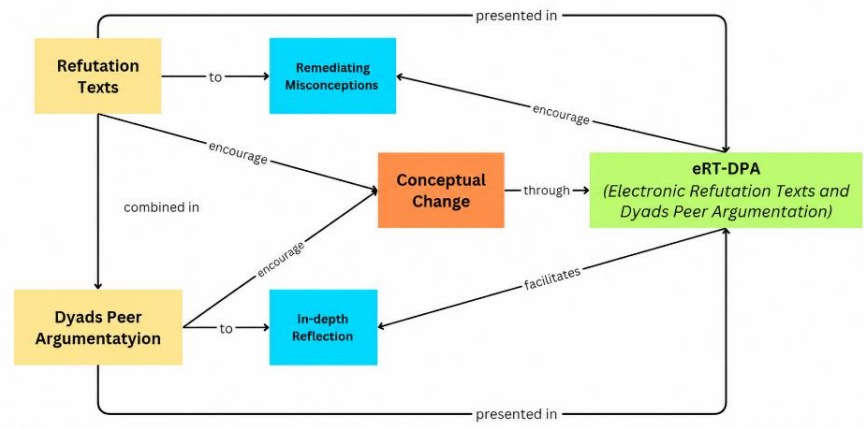


Figure 2. Integration Framework of eRT-DPA

3.2. Design

Based on the literature analysis and initial student diagnostic findings, an initial design for the electronic Refutation Texts and Dyads Peer Argumentation (eRT-DPA) approach was developed, consisting of two complementary main components, namely electronic refutation texts and paired discussion activities (dyads peer argumentation). The first component, electronic refutation texts, was developed based on a tripartite structure proven effective in previous research, including (1) the presentation of common misconceptions that explicitly reflect students' thinking patterns, (2) a direct refutation of these misconceptions, and (3) a correct scientific explanation accompanied by logical arguments or supporting illustrations, as shown in Figure 3. The text content was structured based on the results of the misconception identification during the analysis stage, thus aligning with the context of students' misconceptions.

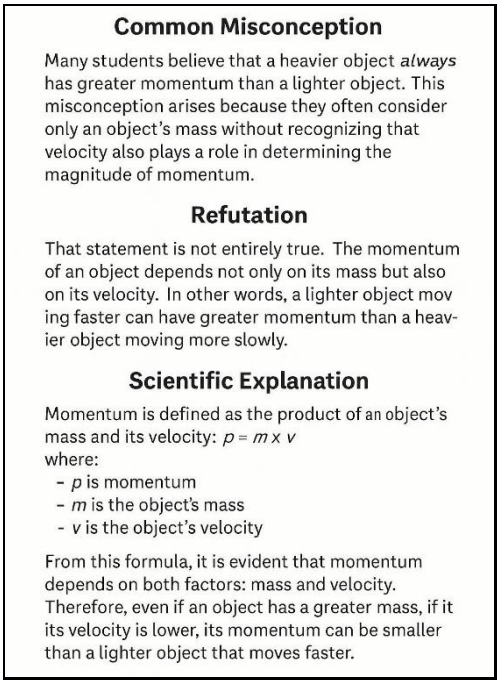


Figure 3. Design of Refutation Texts

The second component of eRT-DPA is the dyads peer argumentation activity, systematically designed to support the clarification and restructuring of students' understanding after reading the refutation texts. The discussion takes place in a structured worksheet format that facilitates concept exploration through guiding questions, addressing a controversial but common conceptual claim found in students' misconceptions. In this discussion assignment, students are asked to (1) express agreement or disagreement with the claim, (2) provide reasons or logical arguments to support their opinion, (3) cite scientific evidence supporting the argument (e.g., laws or formulas of physics), and (4) write a rebuttal if they disagree with the claim.

Next, students reflect on the discussion process through two important sections, that is (1) what they learned from the discussion, and (2) whether their understanding of the concepts of momentum and impulse changed after the discussion. They are also asked to rephrase the explanation of the concept of momentum as if explaining it to someone who still holds the initial misconception. This process aims to internalize new understanding and strengthen scientific cognitive structures through peer teaching (teaching as learning). The design of the DPA worksheet is shown in Figure 4.

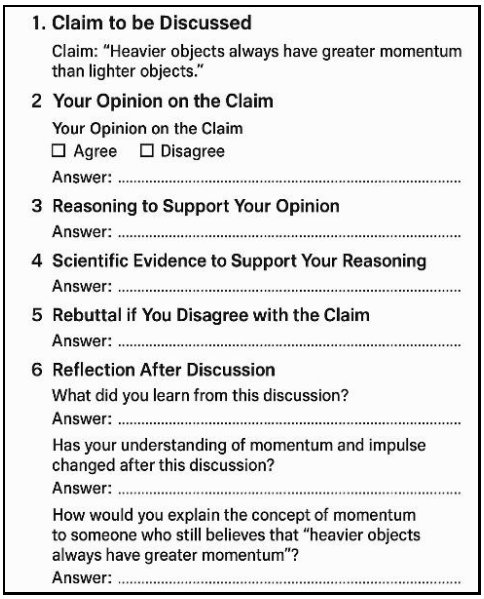


Figure 4. Design of DPA Worksheet

3.3. Development

Next, the eRT-DPA was developed in digital media, including refutation text and DPA worksheets that can be used both online and offline. The results of the eRT-DPA development are shown in Figure 5.

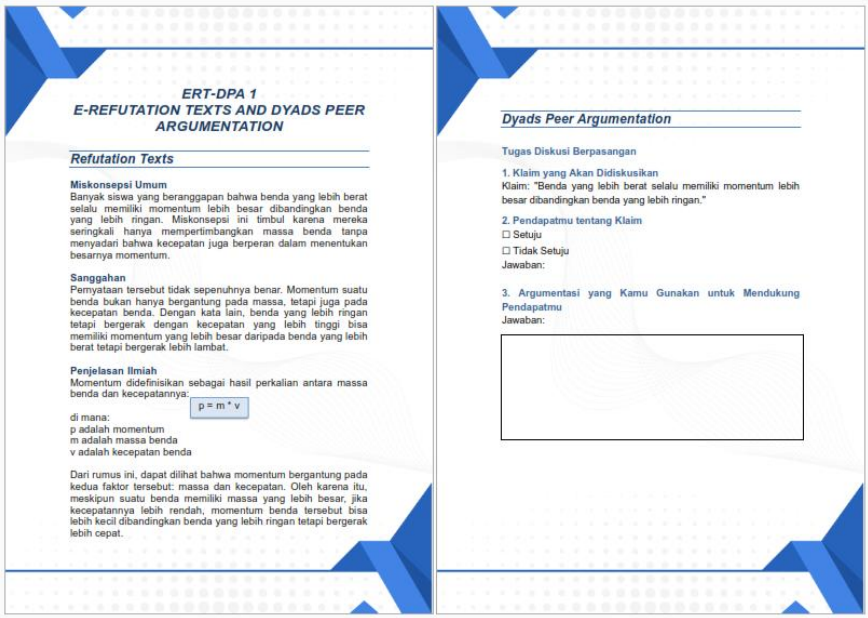


Figure 5. The eRT-DPA Development

This product was then validated by three experts, including two physics education lecturers and one physics teacher. The validation process was conducted using the Learning Objects Review Instrument (LORI) version 1.5, which covers key dimensions such as content quality, alignment with learning objectives, feedback and adaptability, learner motivation, presentation design, interactivity, accessibility, reusability, and adherence to technical standards. A summary of the three validators' assessment results of the eRT-DPA product is shown in Table 4.

Table 4. The Result of Expert Validation

No.	Assessment Dimension	Average Score	Categories
1	Content Quality	4.67	Very Feasible
2	Suitability to Learning Objectives	4.67	Very Feasible
3	Feedback and Adaptability	4.33	Feasible
4	Learning Motivation	4.33	Feasible
5	Presentation Design	4.00	Feasible
6	Interactivity	4.33	Feasible
7	Accessibility	4.33	Feasible
8	Reusability	4.00	Feasible
9	Compliance with Technical Standards	4.00	Feasible
Total Average		4.30	Feasible

The assessment results showed that all dimensions received an average score between 4.00 and 4.67, categorized as "Feasible" to "Very Feasible." The content quality and suitability to learning objectives dimension received the highest score (4.67), indicating that the eRT-DPA material was substantively valid and highly relevant for addressing physics misconceptions. Other dimensions, such as interactivity, learning motivation, and accessibility, also received high scores, indicating that the material was engaging and easy for students to use.

The validators' suggestions were more technical and required minor improvements, such as adding supporting visuals at the beginning of the text to increase its appeal, simplifying the instructional language in the discussion worksheets to make them more communicative, and adding bookmark navigation for greater user-friendliness. Based on the initial validation results, which were categorized as "Feasible," and the improvements made, the product was declared ready for implementation in the learning process.

3.4. Implementation

The implementation phase aimed to apply the eRT-DPA approach to address student misconceptions regarding momentum and impulse. This activity involved 29 eleventh-grade students in the 2025/2026 academic year from a public high school in Indramayu Regency, Indonesia. Prior to implementing the eRT-DPA approach, a pre-test was conducted with INFORMI to determine the distribution of student misconceptions. The implementation then took place in two main sessions. In the first session, students independently studied refutation texts in digital format using computers or mobile devices. One week after the first session, a second session, a dyad-peer argumentation session, was held. In this session, students were paired and given discussion worksheets containing conceptual claims directly related to the texts they had previously read. The discussion assignments required students to express their opinions on the claims, develop arguments, present scientific evidence, provide rebuttals, and reflect on changes in understanding that occurred after the dialogue. The discussions took place in class under teacher supervision.

During the DPA session, the physics teacher acted as a facilitator by guiding the paired discussions and providing conceptual clarification when necessary. Students completed the structured worksheets by stating their positions toward the conceptual claims, providing reasons and relevant scientific evidence, formulating rebuttals, and reflecting on their understanding. These activities describe the intended implementation of the DPA component; however, the quality of the resulting arguments was not assessed as a separate outcome in this study. After completing the eRT-DPA activities, students completed the INFORMI post-test to identify changes in their conception categories. The implementation phase is shown in Figure 6.



Figure 6. The Implementation of eRT-DPA

3.5. Evaluation

The evaluation was conducted to measure changes in students' conceptions after participating in eRT-DPA-based learning using INFORMI. The pre-test and post-test distributions were compared descriptively to identify whether responses shifted away from Misconception and No Understanding toward Partial Understanding and Sound Understanding. Accordingly, the results indicate changes in conception categories after the complete eRT-DPA sequence but do not directly document the internal cognitive process of conceptual change. The percentage distribution of conceptions categories before and after the implementation of the eRT-DPA approach is shown in Figure 7.

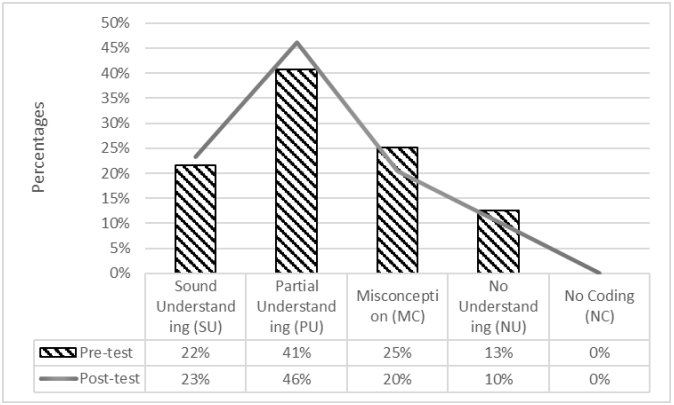
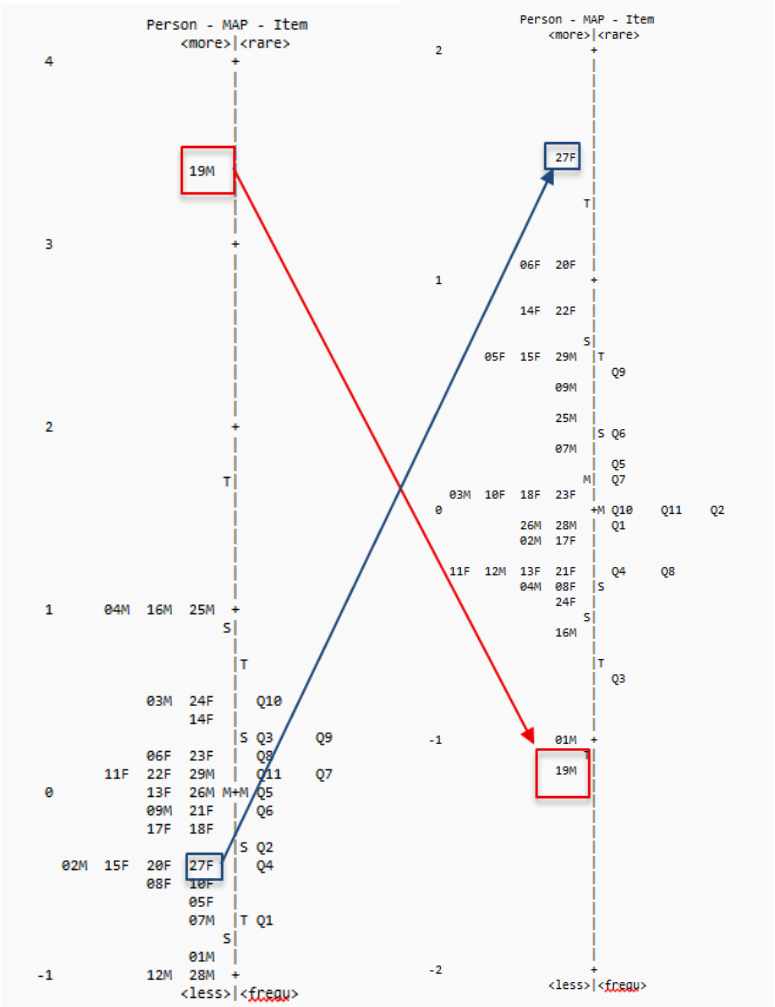


Figure 7. Percentage Distribution of Students' Conceptions Before and After the Implementation of the eRT-DPA Approach

Figure 7 shows the distribution of students' conception categories before and after the implementation of eRT-DPA. The proportion of responses classified as Misconception decreased from 25% in the pre-test to 20% in the post-test. Partial Understanding increased from 41% to 46%, while Sound Understanding increased slightly from 22% to 23%. Meanwhile, No Understanding decreased from 13% to 10%. Although these changes were relatively modest, the overall distribution shifted descriptively away from Misconception and No Understanding toward categories representing partial or scientifically sound understanding. No responses were classified as No Coding, indicating that all four tiers were completed and could be categorized.

The category-based results were complemented by the Rasch analysis presented in the Wright maps in Figure 8. Before the intervention, most students were located within the −1 to +1 logit range, with several students positioned below the difficulty level of some items. In the post-test map, more students appeared within the 0 to +2 logit range, and some were located above items that had previously been relatively difficult. This pattern descriptively suggests that more students occupied higher person measure locations relative to the assessed items after the implementation of eRT-DPA. However, the Wright maps should be interpreted as complementary descriptive evidence rather than as proof of a statistically significant increase in conceptual ability.



(a) (b)

Figure 8. (a) Distribution of Students During Pre-test; (b) Distribution of Students During Post-test

According to conceptual change theory, changes in understanding may occur when learners encounter information that conflicts with their existing conceptions and are encouraged to reconsider their conceptual frameworks (Posner et al., 1982; Ruiz-Martín & Bybee, 2022). Within

eRT-DPA, the refutation texts were designed to make the conflict between common misconceptions and scientific explanations explicit, while dyads peer argumentation provided opportunities for students to articulate, compare, and reconsider their explanations through social interaction. In the present study, this represents the intended instructional role of DPA rather than an empirically tested effect of argumentation quality. Because the students' discussions were not systematically recorded or analyzed using an argumentation framework, the findings cannot determine how successfully individual dyads constructed scientific arguments or which characteristics of their discussions contributed to the observed changes in conception. Previous studies have reported that explicit refutation and dialogic interaction can support students in reconsidering and restructuring their existing conceptions (Asterhan & Resnick, 2020; Li et al., 2023; Mansour et al., 2016).

Within the intended eRT-DPA sequence, the electronic refutation texts first made the targeted misconceptions explicit, directly refuted them, and presented scientific explanations. The subsequent DPA activities required students to state their positions, justify them using relevant physical principles or evidence, compare explanations with peers, formulate rebuttals, and reflect on their understanding. These activities were intended to externalize students' reasoning and make inconsistencies between their initial conceptions and scientific explanations more visible. The observed pattern, consisting of a descriptive decrease in Misconception and No Understanding accompanied by an increase in Partial Understanding and Sound Understanding, is consistent with this intended instructional sequence. However, because eRT and DPA were implemented as one integrated intervention and the discussions were not systematically recorded or analyzed, the present study cannot isolate the contribution of DPA or examine the relationship between students' argumentation processes and changes in their conception categories.

Despite the descriptive shift in conception categories, 20% of the post-test responses remained classified as Misconception. The present data do not allow the specific reasons for the persistence of these misconceptions to be determined. Previous research suggests that possible explanations may include the relative stability of students' prior conceptions, insufficient time for consolidation, and differences in how students process refutational information and peer discussion. These explanations should therefore be treated as plausible interpretations rather than conclusions derived directly from the present data.

Beyond the aggregate distribution of conceptual categories, the Wright maps also revealed substantial variation in individual response patterns. Student 19M occupied a relatively high person-measure location in the pre-test but a much lower location in the post-test, whereas student 27F showed the opposite pattern. These contrasting cases indicate that the aggregate changes did not occur uniformly across students. However, the available diagnostic data do not explain why these individual differences occurred. Interviews, response-process data, or systematic classroom observations would be required to determine whether the patterns reflected unstable understanding, response inconsistency, differences in engagement, or other factors.

Although some students remained in the misconception category after the intervention, the observed changes suggest that eRT-DPA has potential as a structured approach for addressing misconceptions in momentum and impulse. Through the integration of explicit refutation texts and paired discussion activities, eRT-DPA provides opportunities for students to examine, compare, and reconsider their initial conceptions. Within the scope of the present study, however, eRT-DPA should primarily be interpreted as a conceptual intervention, as the evaluation focused on changes in students' conception categories. Its potential contributions to argumentation skills, critical thinking, metacognition, and scientific dispositions require separate empirical investigation. Therefore, although the findings did not indicate the complete elimination of misconceptions, eRT-DPA may be considered a promising approach for further development and examination across broader conceptual and educational contexts.

Several limitations should be considered when interpreting the findings of this study. First, the implementation involved a relatively small sample of 29 students from one senior high school selected purposively. Therefore, the findings may not represent students from different schools, educational settings, or levels of prior knowledge. Second, the study employed a one-group pre-test–post-test design without a comparison group. Consequently, the observed changes in students' conception categories cannot be attributed exclusively to eRT-DPA, because other instructional or

contextual factors may also have contributed to the results. Third, the evaluation focused on immediate changes in conception categories after the intervention, and no delayed post-test was administered. Thus, the study cannot determine whether the observed conceptual changes were retained over time.

Fourth, the developed eRT-DPA materials focused on selected misconceptions concerning momentum and impulse. Therefore, the findings cannot yet be generalized to all misconceptions within these topics or to other areas of physics. Fifth, although structured paired argumentation formed an integral part of the developed intervention, the study did not systematically record, code, or assess the quality of students' argumentative dialogue. Consequently, the present findings show changes in students' conception categories after participation in the complete eRT-DPA sequence but do not establish whether the argumentation process was successfully enacted by every dyad or how particular argumentative interactions contributed to conceptual change.

Future studies should involve larger and more diverse samples and employ experimental or quasi-experimental designs with comparison groups to provide stronger evidence of the instructional contribution of eRT-DPA. Delayed post-tests are also needed to examine the retention of conceptual change. In addition, the approach should be developed for a broader range of misconceptions and physics topics while maintaining alignment among the identified misconceptions, refutation texts, argumentation tasks, and diagnostic assessment. Future research may also use validated argumentation rubrics, classroom observations, audio or video recordings, and discourse analysis to examine how students' claims, evidence, reasoning, and rebuttals contribute to conceptual reconstruction.

4. Conclusion

The development of electronic Refutation Texts and Dyads Peer Argumentation (eRT-DPA) produced a learning resource that integrated explicit refutation of common misconceptions with structured paired discussion and reflection. Expert validation indicated that the developed product was feasible for use in physics learning. Following its implementation, the proportion of responses classified as misconceptions decreased, while the proportions of partial and sound understanding showed a descriptive increase. These findings suggest that eRT-DPA has potential as a structured conceptual intervention for addressing misconceptions concerning momentum and impulse. Nevertheless, because the study involved a small sample, no comparison group, and descriptive pre-test–post-test analysis, the results should be interpreted as preliminary evidence rather than definitive proof of instructional effectiveness.

For physics teachers, the findings highlight the importance of identifying students' specific misconceptions before instruction rather than relying solely on explanations of formulas and procedures. Teachers may use four-tier diagnostic questions or other formative assessments to identify confidently held incorrect conceptions and then prepare refutation texts that explicitly state the misconception, reject it, and provide a scientific explanation supported by relevant physical relationships or evidence. The texts can subsequently be combined with structured paired discussions in which students state their positions, justify their reasoning, respond to conflicting explanations, and reflect on changes in their understanding. In this way, eRT-DPA can serve as a practical framework for connecting diagnostic assessment with targeted conceptual remediation. Its application to other misconceptions and physics topics should be further examined through studies involving broader samples, comparison groups, delayed assessments, and systematic analysis of students' discussion processes.

Author Contributions

Hera Novia: Conceptualization, Supervision, Writing - Reviewing and Editing. Nuzulira Janeusse Fratiwi: Conceptualization, Data curation, Writing - Original draft preparation. Nurdini: Methodology, Visualization, Writing - Original draft preparation. Shita Ayu Amalia: Investigation. Dewi Alya Pramanik: Investigation, Writing - Original draft preparation. Noeri Denia Poetri: Inverstigation, Writing - Original draft preparation. Achmad Samsudin: Supervision, Writing - Reviewing and Editing. Bayram Costu: Writing - Reviewing and Editing. All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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