Journal of Advanced Sciences and Mathematics Education
Volume 5, Issue 2, 541 - 553
e_ISSN: 2798-2351
DOI: 10.58524/jasme.v5i2.801

Investigating students' conceptual change in learning newton's laws through a project-based learning design informed by understanding by design

Jovi Yuzzer Budiman* Universitas Pendidikan Indonesia, INDONESIA

Achmad Samsudin Universitas Pendidikan Indonesia, INDONESIA

Ahmad Aminudin Universitas Pendidikan Indonesia, INDONESIA

Article Info

Article history:

Received: Aug 31, 2025
Revised: Nov 13, 2025
Accepted: Dec 27, 2025

Keywords:

Conceptual Change; Misconception; Newton's Laws; Project-Based Learning; Understanding by Design.

Abstract

Background: Misconceptions related to force and Newton's Laws continue to be widely observed in secondary physics classrooms, often emerging from students' everyday reasoning and instructional approaches that prioritize formula application over conceptual understanding.
Aim: This study seeks to examine how a Project-Based Learning design informed by the Understanding by Design framework supports students' conceptual change in learning Newton's Laws.
Method: The study employed a mixed-methods experimental design involving Grade XI high school students. Students' conceptions were identified using a four-tier diagnostic test administered before and after instruction, complemented by questionnaires and semi-structured interviews. Quantitative analysis focused on conceptual change categories and N-change values, while qualitative data were used to explore students' reasoning processes during learning activities.
Results: The results show that students initially demonstrated a high prevalence of misconceptions, particularly in relation to Newton's Third Law. Following the learning intervention, several students exhibited shifts toward scientifically accepted conceptions. Nevertheless, the overall magnitude of conceptual change remained low, indicating that while improvement occurred, it was not evenly distributed across students.
Conclusion: The findings suggest that a PjBL approach guided by the UbD framework can facilitate conceptual change in learning Newton's Laws, especially in addressing persistent misconceptions. However, the limited level of change highlights the need for more refined instructional designs, longer learning durations, and the integration of isomorphic diagnostic assessments to achieve stronger and more consistent conceptual development.

To cite this article: Budiman, J, Y., Samsudin, A., Aminudin, A. (2025). Investigating Students' Conceptual Change in Learning Newton's Laws through a Project-Based Learning Design Informed by Understanding by Design. *Journal of Advanced Sciences and Mathematics Education, 5(*2), 541-553.

INTRODUCTION

The persistence of misconceptions in physics education represents a serious challenge that continues to affect the quality of science learning (Guerra-Reyes et al., 2024; Resbiantoro et al., 2022). This issue is urgent because misconceptions are not simple errors but stable patterns of thinking that shape how students interpret physical phenomena (Batlolona & Jamaludin, 2024; Dellantonio & Pastore, 2021). Once these patterns are formed, they tend to resist instructional correction. In secondary schools, this problem becomes more pronounced as students encounter increasingly abstract scientific concepts. Physics concepts that require theoretical reasoning are particularly vulnerable to misinterpretation. Among these, force and Newton's Laws are frequently identified as problematic areas. Students often attempt to reconcile formal explanations with everyday

***Corresponding author:**
Jovi Yuzzer Budiman, Universitas Pendidikan Indonesia, INDONESIA
jovi@upi.edu

experiences that appear more intuitive. Consequently, systematic investigation into misconceptions related to Newton's Laws remains highly necessary.

This urgency is closely linked to the fundamental role of Newton's Laws in the structure of physics knowledge (Ferrarelli & Iocchi, 2021; May, 2023). These laws serve as the foundation for understanding motion, interaction, and causality in physical systems. Without a solid conceptual grasp of Newton's Laws, students face difficulties when learning more advanced topics. Despite their importance, many students fail to develop a coherent understanding of these principles (Fries et al., 2021; Reiser et al., 2021). Instruction frequently emphasizes mathematical manipulation rather than conceptual reasoning. As a result, students may succeed in solving numerical problems while misunderstanding the underlying concepts. Such learning outcomes indicate a separation between procedural performance and conceptual comprehension. Addressing this separation is a central concern in contemporary physics education.

A major factor contributing to misconceptions in Newton's Laws is students' reliance on everyday reasoning. Daily experiences with motion often lead students to associate force directly with visible movement. These intuitive interpretations conflict with Newtonian principles but appear reasonable from a non-scientific viewpoint. Once accepted, such ideas become deeply embedded in students' thinking. Conventional classroom instruction often does not explicitly challenge these beliefs (Lorenz, 2021; Scully et al., 2021). Instead, learning activities may reinforce them by focusing on repetitive problem-solving routines. Opportunities for students to reflect on their assumptions are therefore limited. This situation underscores the need for instructional approaches that actively engage students' prior conceptions.

Research in science education has shown that changing students' conceptions is a complex and gradual process (Khishfe, 2023; Li et al., 2023). Conceptual change does not occur simply by presenting correct explanations. Students must recognize inconsistencies between their existing ideas and scientific concepts. This recognition often requires active participation and cognitive engagement. Learning environments that encourage questioning and reflection are therefore essential (Liu et al., 2023; Mohamad & Tasir, 2023). Through discussion and inquiry, students can examine and revise their thinking. However, creating such environments requires careful instructional planning. This need highlights the importance of structured learning designs in physics education.

One instructional approach that aligns with these requirements is Project Based Learning (Bielik et al., 2025; Zhao et al., 2023). This approach emphasizes active student involvement through meaningful tasks and real-world contexts. By engaging in projects, students are encouraged to apply concepts rather than memorize formulas. Project activities also promote collaboration and communication among learners. In physics classrooms, these features can help expose students' misconceptions. As students test their ideas through investigation, they are prompted to reconsider their understanding. Such experiences support the process of conceptual change (Kozinets, 2022; Sorensen et al., 2021). Nevertheless, the effectiveness of Project Based Learning depends on how it is implemented and guided.

To provide structure to instructional implementation, the Understanding by Design framework offers a useful perspective (Ahshan, 2021; Craig et al., 2022). This framework emphasizes planning instruction by starting with clear learning goals. Teachers are encouraged to identify the core concepts students should understand. Learning activities and assessments are then designed to support those goals. In physics education, this approach helps maintain a focus on conceptual understanding. It also promotes coherence between instruction and assessment (Elshami et al., 2021; Reiser et al., 2021). When applied thoughtfully, Understanding by Design can guide meaningful learning experiences. However, its effectiveness in addressing misconceptions requires empirical examination.

Although Project Based Learning and Understanding by Design have been widely discussed in educational research (Beneroso & Robinson, 2022; Markula & Aksela, 2022), they are often examined independently. Studies suggest that each approach can enhance student engagement and learning outcomes. However, limited research has explored their integration in physics learning contexts. In particular, few studies focus on how this integration influences conceptual change in Newton's Laws. Moreover, many existing studies rely on traditional assessment tools. Such tools often fail to capture the depth of students' misconceptions (Messer et al., 2024; Sajja et al., 2025). Diagnostic instruments like four-tier tests offer richer insights into students' reasoning. The limited use of these instruments reveals a gap in current research.

Given these considerations, further investigation into integrated instructional designs is clearly warranted (Abuhassna et al., 2024; Crompton & Sykora, 2021). Combining Project-Based Learning with the Understanding by Design framework offers a promising direction. This integration has the potential to align active learning with clear conceptual goals. When supported by diagnostic assessments, it allows for deeper analysis of student understanding. Newton's Laws provide an appropriate context due to their foundational role and conceptual difficulty (Ding et al., 2024; Pisano & Bussotti, 2022). Examining how students' conceptions change within this context can inform instructional practice. Such research contributes to both theory and classroom implementation. Ultimately, it aims to support more effective strategies for reducing misconceptions in physics learning.

Research in physics education consistently shows that misconceptions in force and Newton's Laws are persistent because students rely heavily on everyday reasoning that conflicts with formal physics concepts. This condition limits the effectiveness of conventional instruction that emphasizes procedural problem solving rather than conceptual understanding. Instructional innovations have therefore been explored to address this issue. In studies on Newton's Laws, Utami et al. (2025) demonstrated that STEM-based Project-Based Learning can enhance students' scientific literacy, although conceptual change was not examined in depth. This suggests that performance improvement does not automatically indicate misconception resolution. From an instructional design perspective, the Understanding by Design framework promotes backward planning to align learning goals, instruction, and assessment around core conceptual understandings. However, empirical evidence linking UbD directly to misconception reduction in physics learning remains limited. The conceptual rigor of Newton's Laws is well established in scientific research. DiLisi (2025) emphasizes their foundational role in classical mechanics, while Zhao et al. (2025) and (Ren et al., 2025) illustrate their application in complex mechanical and stability systems. Further studies by Liu et al. (2025), Nyiembui et al. (2025), Garcia-Guarin (2025), Schussnig et al. (2025) and Manso & Cabo (2025) demonstrate the broad use of Newtonian principles in nonlinear dynamics, structural analysis, and computational modeling. Although these studies are not educational in nature, they highlight the contrast between the advanced application of Newton's Laws in scientific research and students' persistent conceptual difficulties. This contrast reveals a clear research gap, indicating the need for integrative studies that combine Project-Based Learning, Understanding by Design, and diagnostic assessment tools to examine students' conceptual change in learning Newton's Laws.

The persistence of misconceptions in learning Newton's Laws suggests that many physics classrooms still struggle to support students' conceptual understanding effectively. Although students may demonstrate procedural success in solving numerical problems, this success often masks fragile or incorrect conceptual reasoning. Instructional approaches that emphasize activity and engagement, such as Project-Based Learning, have been shown to improve participation and learning outcomes, yet evidence indicates that engagement alone does not guarantee conceptual reconstruction. At the same time, the Understanding by Design framework offers a structured way to align learning objectives, instructional activities, and assessment with core conceptual goals.

However, its potential contribution to addressing misconceptions in physics learning has received limited empirical attention. For this reason, integrating Project-Based Learning within an Understanding by Design framework represents a pedagogically sound approach that warrants closer investigation, particularly in relation to students' conceptual change.

A review of existing studies reveals that most research has examined Project-Based Learning and Understanding by Design as separate instructional strategies. Many studies emphasize outcomes such as achievement or scientific literacy, while providing limited insight into how students' underlying conceptions change during instruction. Furthermore, investigations that focus explicitly on misconceptions in Newton's Laws often rely on conventional assessment tools that are unable to capture students' reasoning in depth. Research employing diagnostic instruments designed to reveal conceptual change, such as multi-tier tests, remains relatively scarce. Consequently, there is insufficient empirical evidence explaining how integrated instructional designs influence the persistence or transformation of misconceptions. This lack of integrative and diagnostically grounded research constitutes a clear gap in the current literature.

In response to this gap, the present study aims to examine students' conceptual change and misconceptions in learning Newton's Laws through the implementation of Project-Based Learning informed by the Understanding by Design framework. The study seeks to explore how the integration of these two approaches supports students' conceptual understanding as revealed through diagnostic assessment. It is expected that students participating in this instructional design will demonstrate positive shifts toward scientifically accepted conceptions, although the degree of conceptual change may vary across different aspects of Newton's Laws. By focusing on conceptual change rather than surface-level performance, this study intends to contribute a more nuanced understanding of how instructional design influences learning in physics.

METHOD

Research Design

This study adopted a mixed-methods design with a pretest–posttest orientation to explore students' conceptual change in learning Newton's Laws. The selection of a mixed-methods approach was driven by the need to capture both the measurable outcomes of learning and the qualitative dimensions of students' reasoning processes. Quantitative data were used to identify shifts in students' conceptual understanding before and after the instructional intervention, while qualitative data provided deeper insight into how students interpreted, justified, and reconstructed their understanding of physical concepts. This combination allowed the study to move beyond surface-level achievement and examine learning as a process of conceptual transformation. The instructional intervention was implemented through Project-Based Learning and systematically guided by the Understanding by Design framework. Project-Based Learning was employed to engage students in meaningful inquiry and problem-solving activities related to Newton's Laws, encouraging active participation and conceptual exploration. At the same time, the Understanding by Design framework ensured that learning objectives, instructional activities, and assessment strategies were coherently aligned around clearly defined conceptual goals. This alignment was intended to support students in developing a deeper and more integrated understanding of Newtonian principles rather than focusing solely on task completion or procedural accuracy. To enhance methodological clarity, the overall research procedure is illustrated in Figure 1, which outlines the sequential stages of the study from initial problem identification to data analysis and interpretation. The inclusion of a visual representation was intended to provide readers with a concise overview of the research flow and to improve transparency in the methodological process. By visually summarizing the instructional design, assessment stages, and analytical procedures, the figure supports a clearer understanding of how the research components were interconnected throughout the study.

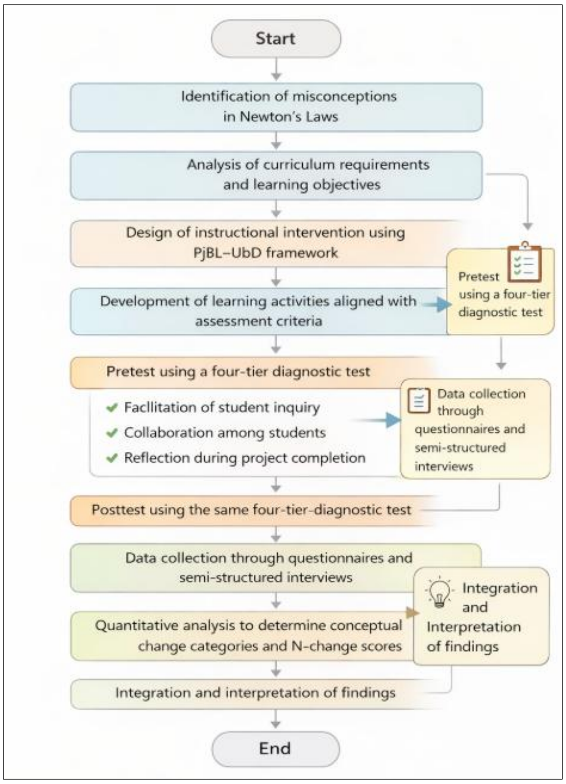


Figure 1. Flowchart of the research design and procedure.

Figure 1 depicts the progression of the study, starting from the identification of learning problems associated with misconceptions in Newton's Laws, followed by instructional planning and classroom implementation. The figure also highlights the role of diagnostic assessment before and after the intervention, as well as the stages of data analysis and interpretation.

Participants

The participants were Grade XI high school students enrolled in a physics course focusing on Newton's Laws. A purposive sampling technique was employed to ensure alignment between the research objectives and the curriculum being taught. All participants had previously received instruction in basic mechanics but had not been exposed to Project-Based Learning designed using the Understanding by Design framework. The research was conducted within a regular classroom environment to preserve authentic learning conditions. Ethical considerations were addressed by ensuring voluntary participation and anonymity of student responses.

Instrument

The primary instrument used in this study was a four-tier diagnostic test designed to examine students' conceptual understanding and identify misconceptions related to Newton's Laws. The test combined multiple-choice items, reasoning selections, and confidence ratings to capture both the accuracy of responses and the certainty underlying students' thinking. This format enabled a more nuanced analysis of students' conceptual states compared to conventional assessments. To complement the diagnostic data, questionnaires and semi-structured interviews were administered to explore students' learning experiences during the intervention, as reflected in the research flow presented in Figure 1.

Data Analysis

Quantitative data obtained from the four-tier diagnostic test were analyzed by comparing pretest and posttest results to identify patterns of conceptual change and levels of N-change. Descriptive analysis was used to summarize shifts in students' understanding across different conceptual categories. Qualitative data from questionnaires and interviews were analyzed thematically to reveal recurring patterns in students' reasoning and reflections on the learning process. The final stage involved integrating quantitative and qualitative findings to develop a comprehensive interpretation of how the Project-Based Learning design informed by the Understanding by Design framework supported students' conceptual change.

RESULTS AND DISCUSSION

Results

Comparison of Students' Initial and Final Understanding of Newton's Laws

The initial assessment revealed noticeable differences in students' conceptual understanding of Newton's Second Law and Newton's Third Law. As illustrated in Figure 2, students demonstrated greater difficulty with concepts related to Newton's Third Law prior to instruction. A higher proportion of students fell into the categories of misconception and partial understanding for this law compared to Newton's Second Law. These findings suggest that action–reaction concepts posed substantial conceptual challenges at the beginning of the learning process.

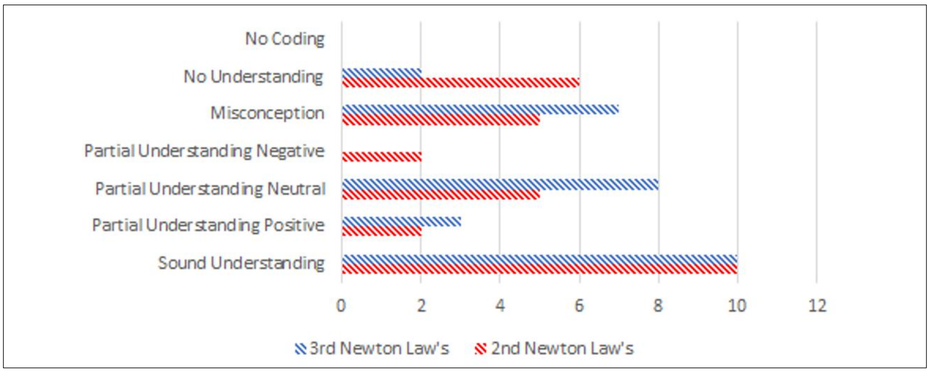


Figure 2. Comparison of students' initial understanding of Newton's Second Law and Newton's Third Law.

Following the implementation of the instructional intervention, changes in students' conceptual understanding were observed. As shown in Figure 3, the number of students achieving sound understanding increased for both laws. The improvement was more evident for Newton's Second Law, although a portion of students remained within the categories of partial understanding and misconception. This pattern indicates that the learning activities contributed to conceptual improvement, but complete conceptual mastery was not achieved by all students.

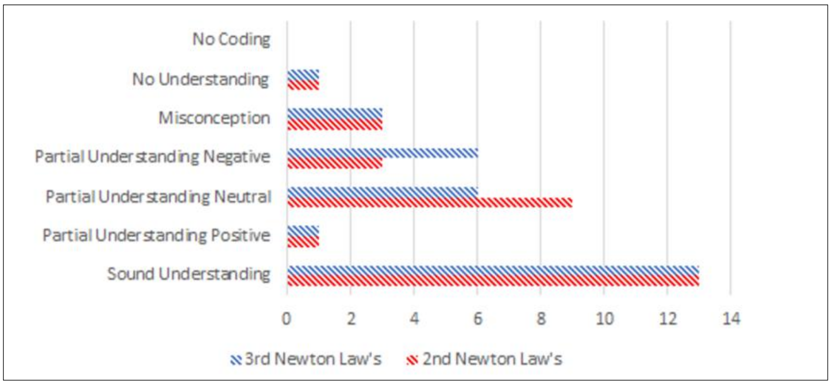


Figure 3. Comparison of students' final understanding of Newton's Second Law and Newton's Third Law.

Percentage Distribution of Conceptual Change

Further analysis examined students' conceptual change through percentage-based categories. For Newton's Second Law, Figure 4 shows that more than half of the students experienced an Acceptable Change, indicating a shift toward more scientifically accurate understanding. However, a notable proportion of students remained in the Not Acceptable category, reflecting either a decline or stagnation in conceptual understanding after instruction.

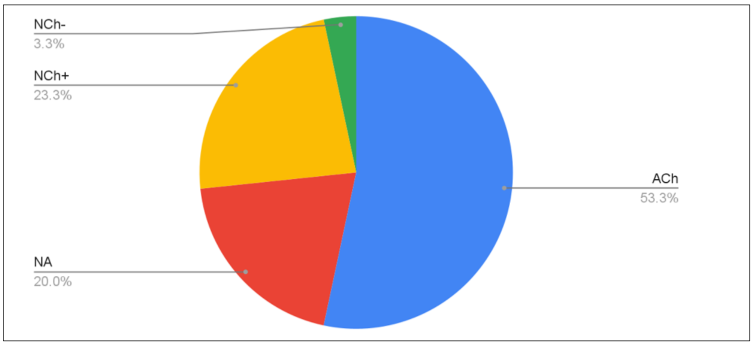


Figure 4. Percentage of students' conceptual change on Newton's Second Law questions.

A slightly different pattern emerged for Newton's Third Law. As presented in Figure 5, although a considerable percentage of students demonstrated Acceptable Change, the proportion of students categorized as Not Acceptable was relatively high. In addition, some students maintained a consistently correct understanding, classified as No Change Positive. These results indicate that conceptual change related to Newton's Third Law occurred unevenly across the student cohort.

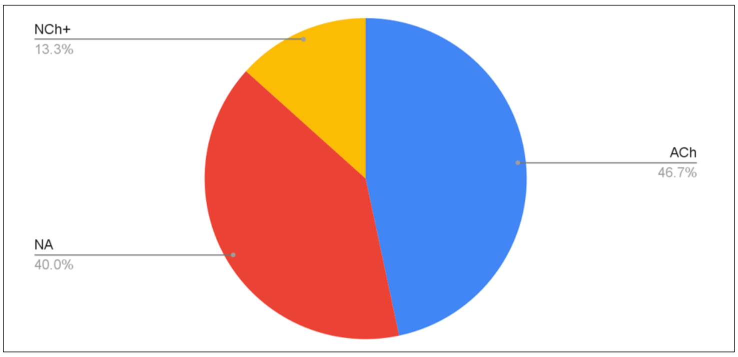


Figure 5. Percentage of students' conceptual change on Newton's Third Law questions.

Magnitude of Conceptual Change Based on N-Change Values

The extent of students' conceptual change was further evaluated using N-change scores. For Newton's Second Law, Figure 8 indicates that the average N-change value fell within the low category. While some students exhibited low to moderate positive change, others experienced negative change, suggesting that the impact of instruction varied considerably among students.

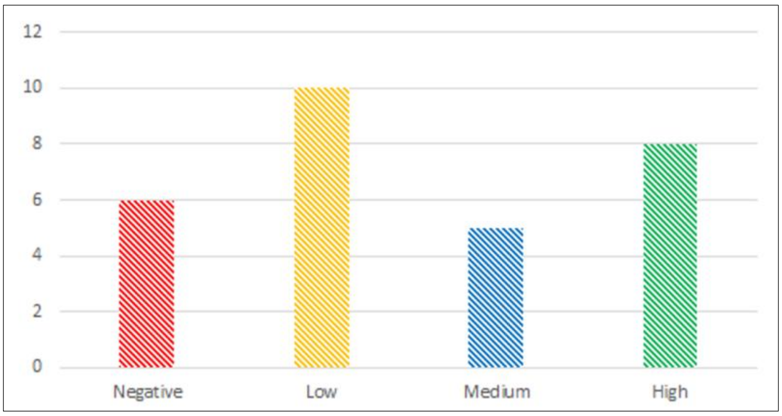


Figure 6. Interpretation of N-change values on Newton's Second Law questions.

A similar trend was observed for Newton's Third Law. As shown in Figure 7, most students were categorized within the low and negative N-change ranges, with relatively few achieving medium or high levels of change. This finding suggests that overall conceptual improvement related to Newton's Third Law remained limited.

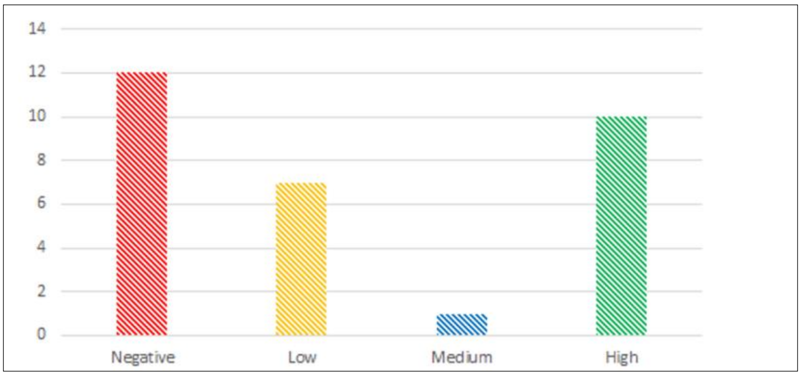


Figure 7. Interpretation of N-change values on Newton's Third Law questions.

The overall distribution of students' N-change scores is summarized in Figure 10. The dominance of negative and low categories confirms that, despite observable improvements in some cases, conceptual gains across the entire group were generally modest.

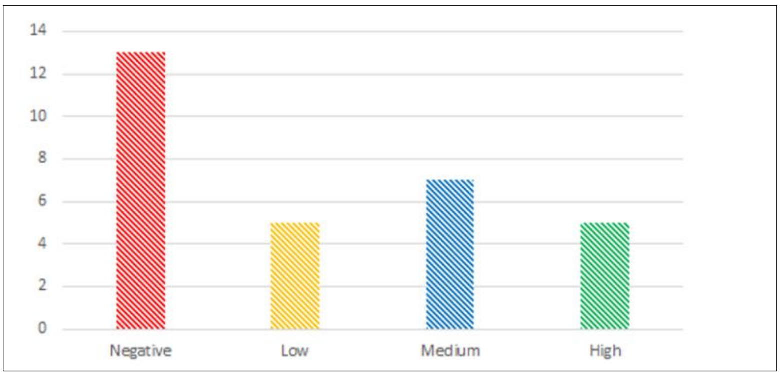


Figure 8. Interpretation of students' overall N-change scores.

Illustration of Individual Conceptual Change

To complement the quantitative findings, examples of individual student responses were examined. As illustrated in Figure 9, the student's pretest response reflected misconceptions regarding action–reaction principles. After instruction, the posttest response presented in Figure 10 demonstrates a shift toward a scientifically accurate explanation, supported by appropriate reasoning. These examples provide concrete evidence of successful conceptual reconstruction at the individual level.

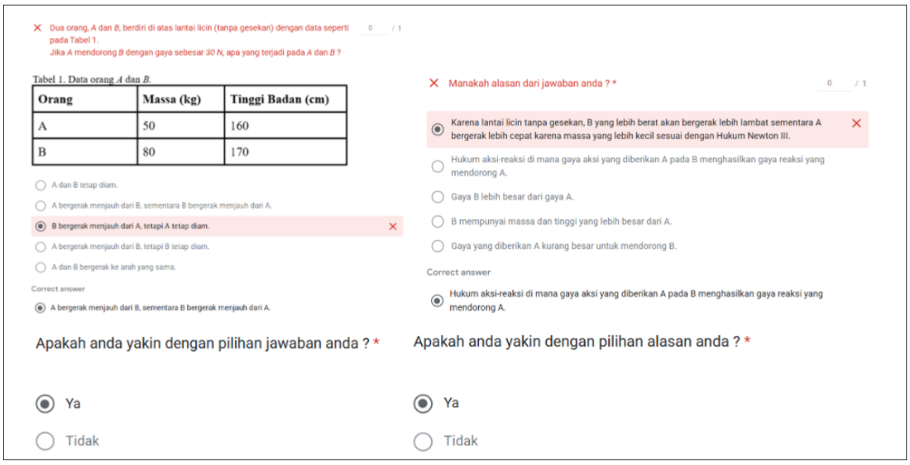
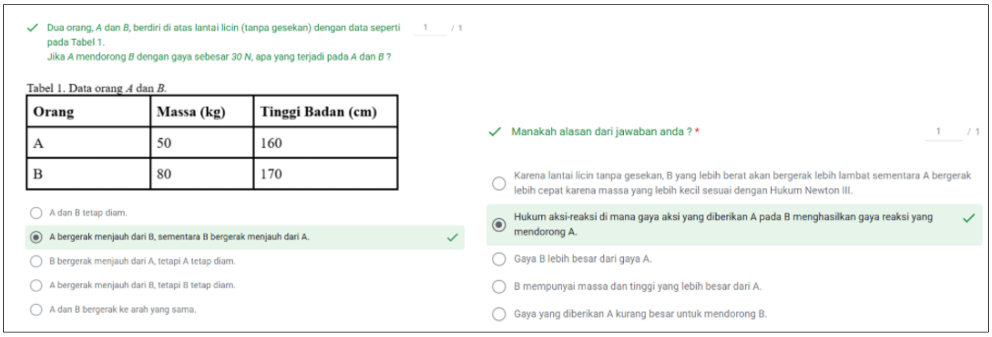


Figure 9. Student response during the pretest on Newton's Third Law question.


Dua orang, A dan B, berdiri di atas lantai licin (tanpa gesekan) dengan data seperti pada Tabel 1.
Jika A mendorong B dengan gaya sebesar 30 N, apa yang terjadi pada A dan B ?

1 / 1

Tabel 1. Data orang A dan B.

Orang	Massa (kg)	Tinggi Badan (cm)
A	50	160
B	80	170

- A dan B tetap diam.
- A bergerak menjauh dari B, sementara B bergerak menjauh dari A.
- B bergerak menjauh dari A, tetapi A tetap diam.
- A bergerak menjauh dari B, tetapi B tetap diam.
- A dan B bergerak ke arah yang sama.

Manakah alasan dari jawaban anda ? *

1 / 1

- Karena lantai licin tanpa gesekan, B yang lebih berat akan bergerak lebih lambat sementara A bergerak lebih cepat karena massa yang lebih kecil sesuai dengan Hukum Newton III.
- Hukum aksi-reaksi di mana gaya aksi yang diberikan A pada B menghasilkan gaya reaksi yang mendorong A.
- Gaya B lebih besar dari gaya A.
- B mempunyai massa dan tinggi yang lebih besar dari A.
- Gaya yang diberikan A kurang besar untuk mendorong B.

Figure 10. Student response during the posttest on Newton's Third Law question.

Discussion

The results of this study reaffirm that misconceptions surrounding force and Newton's Laws remain deeply embedded in students' thinking. The prevalence of non-scientific reasoning prior to instruction suggests that learners often interpret physical phenomena through everyday experiences rather than formal principles. Such reasoning patterns are resistant to change, particularly when instructional practices prioritize procedural problem solving over conceptual meaning. The observed improvement after the instructional intervention indicates that Project-Based Learning can contribute to the development of students' understanding when learning activities are designed to be meaningful and contextually grounded. Similar instructional outcomes were reported by Utami et al. (2025), who found that STEM-based project learning improved students' scientific literacy in the context of Newton's Laws. However, the present findings show that improved performance alone does not necessarily translate into the elimination of misconceptions. This distinction becomes especially evident in students' understanding of Newton's Third Law. Despite engagement in project-based activities, misconceptions related to action–reaction forces persisted for many learners. This suggests that while Project-Based Learning supports engagement and application, it does not automatically trigger deep conceptual restructuring. The findings therefore extend the work of Utami et al. (2025) by demonstrating the importance of explicitly examining conceptual change rather than relying solely on achievement indicators. The relatively modest N-change values further indicate that conceptual development occurred unevenly across students. Some learners demonstrated meaningful progress, while others showed limited or even negative change. This pattern highlights that conceptual change is gradual and requires sustained instructional support. Diagnostic assessment tools are therefore essential for identifying the stability of students' initial conceptions and monitoring their evolution over time. From an instructional design perspective, the Understanding by Design framework offers a coherent structure for aligning learning goals, instructional activities, and assessment. Backward planning encourages teachers to focus on core conceptual understandings rather than fragmented skills. Nevertheless, the present findings suggest that alignment alone is insufficient to guarantee misconception reduction, reinforcing the need for empirical studies that directly examine the role of UbD in conceptual change processes. The persistence of misconceptions becomes more striking when contrasted with the treatment of Newton's Laws in scientific research. DiLisi (2025) emphasizes that Newton's Laws form the conceptual backbone of classical mechanics, serving as a foundation for rigorous theoretical reasoning. In scientific practice, these laws are applied with precision and conceptual clarity, highlighting a sharp contrast with students' fragmented understanding observed in educational settings. This contrast is further illustrated in studies addressing complex mechanical and stability systems. Research by Zhao et al. (2025) and Ren et al. (2025) demonstrates how Newtonian principles are employed to analyze sophisticated physical systems. These applications require a level of conceptual coherence that students often struggle to achieve, underscoring the gap between expert knowledge and novice understanding. Additional research in nonlinear dynamics and structural analysis, including work by Liu et al. (2025), Nyiembui et al. (2025), and Garcia-Guarin (2025), further highlights the breadth of Newtonian applications in contemporary physics. Although these studies are not educational in nature, they reveal how deeply Newton's Laws are embedded in advanced scientific reasoning, thereby emphasizing the conceptual demands placed on learners. Computational and modeling studies conducted by Schussnig et al. (2025) as well as Manso & Cabo (2025) reinforce this perspective by demonstrating the role of Newtonian mechanics in analytical and numerical modeling. The sophistication of these applications contrasts sharply with the misconceptions identified among students, illustrating the enduring challenge of translating foundational scientific principles into meaningful learning. Taken together, the findings of this study highlight a significant gap between the advanced use of Newton's Laws in scientific research and students' persistent conceptual difficulties in physics classrooms. This gap underscores the need for integrative instructional approaches that combine Project-Based Learning, the Understanding by Design framework, and diagnostic assessment tools to examine and support conceptual change. Addressing this challenge is essential for bridging the divide between scientific knowledge and effective physics learning.

Implications

The results of this study suggest that learning designs which integrate Project-Based Learning with the Understanding by Design framework have the potential to support students' conceptual development in physics, particularly when instruction is oriented toward clearly defined conceptual goals. The observed shifts in students' understanding indicate that alignment between intended learning outcomes, learning activities, and assessment can help students move beyond rote procedures toward more meaningful engagement with Newtonian concepts. At the same time, the continued presence of misconceptions, especially in relation to Newton's Third Law, implies that student-centered learning activities alone are not sufficient to ensure deep conceptual change. These findings highlight the need for instructional designs that deliberately address students' initial conceptions and provide structured opportunities for reflection and conceptual clarification. Without such emphasis, intuitive reasoning may persist even in active learning environments. In addition, the use of four-tier diagnostic assessments in this study demonstrates their instructional value beyond measurement purposes. By revealing students' reasoning patterns and levels of confidence, these instruments can inform teachers about which misconceptions are most resistant to change. This implication underscores the importance of incorporating diagnostic assessment as an integral component of concept-focused physics instruction rather than treating assessment as a separate evaluative step.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the investigation was limited to specific concepts within Newton's Laws, namely Newton's Second and Third Laws. As a result, the conclusions drawn may not fully represent students' conceptual change across other areas of physics that involve different forms of reasoning or representational demands. Second, the instructional intervention was implemented within a relatively limited timeframe. Conceptual change is widely recognized as a gradual process, and the duration of the intervention may not have been sufficient to enable all students to reconstruct deeply rooted misconceptions. The prevalence of low N-change values suggests that longer or repeated instructional exposure may be necessary to achieve more substantial conceptual shifts. Third, the study was conducted within a single instructional context and involved a specific group of students. Differences in classroom culture, instructional practices, and students' prior experiences were not examined in detail. These contextual factors may influence the effectiveness of the instructional approach and therefore limit the generalizability of the findings to other educational settings.

Suggestions

Based on the findings and limitations identified, several recommendations can be proposed for future research and instructional practice. Future studies are encouraged to design longer-term learning interventions that allow students multiple opportunities to revisit core concepts, reflect on their understanding, and resolve conceptual conflicts. Extended instructional sequences may provide a clearer picture of how misconceptions evolve over time. Future research may also explore the combination of Project Based Learning and Understanding by Design with additional instructional supports, such as guided conceptual discussions, visual representations, or simulation-based activities. Examining how these elements interact could offer deeper insight into strategies that more effectively support conceptual change, particularly for abstract concepts like Newton's Third Law. Finally, studies involving a wider range of educational contexts and learner characteristics are recommended. Investigations across different schools, grade levels, or instructional environments could help determine how instructional design principles function under varied conditions. Such research would contribute to the development of more flexible and context-sensitive approaches to addressing misconceptions in physics learning.

CONCLUSION

This study explored students' conceptual understanding of Newton's Laws through an instructional design that combined Project-Based Learning with the Understanding by Design framework, focusing on how students' conceptions evolved before and after instruction. The findings show that misconceptions were prominent at the outset, particularly in relation to Newton's Third Law, reflecting the strong influence of everyday reasoning on students' interpretations of physical phenomena. After the intervention, students demonstrated improvement in conceptual understanding, most notably for Newton's Second Law; however, these improvements were not consistent across all learners, and overall conceptual change remained limited. This pattern indicates that engagement in project-based activities, even when guided by clear instructional goals, does not automatically lead to deep conceptual restructuring. The persistence of misconceptions suggests that conceptual change in physics learning requires sustained instructional attention, explicit engagement with students' prior ideas, and continuous diagnostic feedback. Consequently, this study highlights the need for instructional approaches that go beyond activity based learning to more deliberately support students in reconstructing their understanding of foundational physics concepts.

AUTHOR CONTRIBUTIONS STATEMENT

JYB was responsible for the overall research conception and execution, including the design of the instructional model, data collection, data analysis, and the preparation of the initial manuscript draft.
AS contributed to the development of the theoretical framework, the design and validation of research instruments, and provided critical input on the analysis of students' conceptual change and interpretation of findings.
AA contributed to the refinement of the research methodology, the development of the conceptual change analysis framework, and the revision of the manuscript to ensure coherence, academic rigor, and alignment with the study objectives. All authors reviewed, discussed, and approved the final version of the manuscript.

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