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The interplay between recall and understanding in physics: A case of Newton's laws

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Abstract

This conceptual paper explores the interplay between recall and understanding in the context of learning Newton's laws of motion. It examines the theoretical foundations, distinctions, and interconnections between these cognitive processes, highlighting their significance in physics education. Recall, the ability to retrieve previously learned information, is often viewed as a precursor to understanding, which involves the interpretation, explanation, and application of knowledge. By focusing on Newton's laws, this paper demonstrates how hands-on experiments and visual aids can enhance both recall and understanding. The generate-recognize theory is applied to illustrate how students generate hypotheses and recognize relevant concepts during experiments, thereby strengthening their knowledge system. The paper argues that understanding should be the primary goal of education, as it enables learners to make connections, think critically, and apply their knowledge in real-world contexts. The implications for teaching and learning practices are discussed, emphasizing the need for instructional designs that prioritize depth, critical thinking, and application of knowledge. By fostering a deeper understanding of Newton's laws, teachers can create a powerful learning environment that promotes meaningful and lasting learning outcomes, preparing students for success in an increasingly complex and interconnected world.

Keywords: recall, understanding, Newton's laws, cognitive processes, instructional design, physics education

INTRODUCTION

Mastery of physics hinges not only on the ability to recall formulas but on the depth of conceptual understanding they represent. In the context of physics education, particularly when learning Newton's laws of motion, learners must employ various cognitive strategies to encode, store, and retrieve knowledge. Two essential concepts in this process are recall and understanding. Recall is the ability to retrieve previously learned information, while understanding involves the interpretation, explanation, and application of knowledge (Zhai et al., 2024). Using Newton's laws of motion as a framework, this paper examines the dynamic relationship between recall and understanding. Recall allows students to retrieve the three laws and their formulations, but true understanding requires deeper cognitive processes. This includes interpreting the implications of the laws, explaining their applications in various contexts, and using them to solve complex problems (Gjerde & Hagane, 2024; Parra-Zeltzer et al., 2025). Despite their importance, recall and understanding are frequently conflated or used interchangeably, obscuring the relationships between these concepts. This lack of clarity has significant implications for teaching and learning practices. Teachers must design instructional experiences that promote meaningful and lasting learning outcomes by prioritizing both recall and understanding through strategies such as retrieval practice, elaboration, concept mapping, and peer instruction (Anastasiou et al., 2024; Hultberg et al., 2018; Moreira et al., 2019; Sumarni & Okyranida, 2025).

Research has consistently shown that students often hold persistent misconceptions about Newton's laws, which can arise early in their educational careers and

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Contribution to the literature

- This paper contributes to the literature by highlighting the complex relationships between recall and understanding, specifically in the context of Newton's laws of motion, emphasizing that recall is necessary but insufficient for understanding.
- The paper adds to the existing literature by suggesting that instructional experiences should prioritize depth over breadth, promoting critical thinking, problem-solving, and application of knowledge in physics.
- This research contributes to the literature by arguing that understanding should be the primary goal of education, particularly in physics, enabling learners to make connections, think critically and creatively, and apply knowledge in real-world contexts.

persist if left unaddressed. Studies have documented these misconceptions (Kibirige, 2022; Maryani & Atmojo, 2024; Sari et al., 2024; Suhandi et al., 2025; Suwasono et al., 2023) across various educational levels, including elementary school students (Maryani & Atmojo, 2024) and junior high school students (Sari et al., 2024). In Indonesia, physics students commonly hold specific misconceptions, such as believing that heavier objects fall faster, an object's mass can stop it from moving, and motion requires an active force (Syuhendri, 2017). These misconceptions can persist even when students have verbal knowledge of the concepts, as evidenced by their struggles to apply Newton's laws of motion to phenomena like floating, suspending, and sinking objects (Sukariasih et al., 2024). To address these misconceptions, several strategies have been proposed and tested. For example, conceptual problem-solving learning has been shown to enhance students' conceptual understanding of Newton's laws (Diyana & Sutopo, 2024). Additionally, addressing the action-reaction language and implied causality in Newton's third law (Bao & Fritchman, 2021) and contextualizing problems in problem-based learning (Suwasono et al., 2023) have been found to be effective in reducing misconceptions. More recent studies have explored innovative approaches, including the development of e-rebuttal texts (Suhandi et al., 2025), interactive e-modules (Solviana et al., 2024), and analyzing the causes of misconceptions to inform strategies for reduction (Adilah et al., 2025). These findings highlight the importance of targeted instructional strategies in helping students develop a deeper understanding of Newton's laws.

This conceptual paper systematically explores the interplay between recall and understanding in the context of Newton's laws of motion. The paper commences by revisiting the concepts of recall and understanding, laying the groundwork for a comprehensive analysis. This is followed by an examination of the divergent perspectives on recall and understanding, as evident in existing literature. The paper then delves into an overview of the generate-recognize theory, providing a theoretical foundation for understanding the cognitive processes involved in learning and recalling scientific concepts. Following this, the paper delves into the role of experiments in physics education, illustrating how hands-on activities reinforce the generate-recognize theory. The discussion then focuses on Newton's laws and experiments. Finally, the paper explores the virtualization of Newton's laws, highlighting the potential of digital tools to enhance the learning and retention of these fundamental principles in physics.

RECALL AND UNDERSTANDING

The literature emphasizes the inconsistent results on the effectiveness of memory and comprehension, underscoring the necessity of creative teaching strategies. Notably, it has been repeatedly demonstrated that the thoughtful presentation of information and the strategic use of visual aids such as simulations (Almadrones & Tadifa, 2024) and virtual laboratories (Darman et al., 2024) improve recall and comprehension, especially when learning Newton's laws of motion. Furthermore, compared to typical outlines or lists, knowledge maps have been shown to boost memory of lecture material, particularly for students with little prior knowledge (Lambiotte & Dansereau, 1992). This implies that visual aids like outlines and maps can encourage better cohesive recall, which is defined by the retrieval of fewer disparate facts.

In contrast, the efficacy of metaphors in enhancing recall has yielded mixed results. Yarbrough and Gagné (1987) found that the inclusion of metaphors in technical texts did not necessarily facilitate recall. In fact, their study revealed that recall was superior when metaphors were absent, particularly for critical paragraphs within a passage. This suggests that metaphors may not consistently promote recall and may even lead to superficial processing, where learners focus on recalling the metaphor itself rather than integrating it into the broader context. These findings highlight the need for further investigation into the role of metaphors in facilitating recall and understanding, particularly in the context of Newton's laws. Lambiotte and Dansereau (1992) and Yarbrough ad Gagné (1987) agree on the importance of enhancing recall and understanding through strategic presentation methods. However, they

disagree on the effectiveness of specific tools: while Lambiotte and Dansereau (1992) advocate for the use of visual aids like knowledge maps, Yarbrough and Gagné (1987) caution against the use of metaphors, suggesting they may hinder rather than help recall. This comparison underscores the complexity of instructional design and the need for tailored approaches depending on the content and learner characteristics.

Theoretical frameworks on human information processing offer valuable insights into the cognitive mechanisms that underpin recall and understanding. From a cognitive perspective, research suggests that visual information has the unique ability to engage both verbal and nonverbal codes (Hodes, 1998). This dual-coding process underscores the significance of visual literacy in facilitating learning outcomes. Furthermore, the leveraging of nonverbal mental processes to visualize critical information highlights the potential pedagogical benefits of incorporating visual aids into educational materials, thereby enhancing the encoding and retrieval of information related to Newton's laws. The critical role of retrieval (Karpicke & Roediger III, 2008; Moreira et al., 2019; Zhang & Fukumoto, 2023) in facilitating learning has been a longstanding focus of research, with studies underscoring the importance of tailoring retrieval tasks to maximize educational outcomes. Karpicke and Roediger (2008) established that retrieval enhances learning, and more recent investigations have explored the differential impact of various retrieval tasks on learning and comprehension. Endres et al. (2017) conducted an in-depth examination of the effects of different retrieval tasks on learning outcomes, providing valuable insights into the optimal design of retrieval-based instructional strategies.

Endres et al. (2017) compared the effectiveness of prompted recall with free recall, which significantly advanced our understanding of retrieval-based learning processes. It was discovered that prompt recall, which asked students to relate the material to their own experiences, encouraged more complex processing techniques and produced higher understanding scores than free recall. The constructive retrieval hypothesis (CRH) was supported by the researchers' finding that the beneficial impact on understanding was mediated by the application of elaborative methods. According to the CRH, retrieval is maximized when learned content is actively and constructively elaborated, emphasizing the significance of meaningful involvement with the material throughout the retrieval process. The results of Endres et al. (2017) highlight the crucial role that retrieval task design plays in fostering significant learning outcomes and contribute to the expanding corpus of research on the intricate relationship between recall and understanding. Teachers can establish the best learning environment for Newton's laws and help students retain the information by implementing pedagogical tactics that combine retrieval and elaboration. In order to promote more permanent and transferable learning outcomes, this research emphasizes the significance of going beyond simple recall and instead creating instructional challenges that encourage active elaboration and application of taught concepts. The significance of improving recall and comprehension through strategic teaching techniques is acknowledged by both Hodes (1998) and Endres et al. (2017). But they emphasize distinct elements: Endres et al. (2017) stress the importance of retrieval tasks and elaborative tactics, while Hodes (1998) stresses the dual-coding process and the use of visual aids. The complexity of learning and the requirement for a variety of methods to maximize educational results are shown by this contrast.

Effective learning strategies are crucial for knowledge transfer, and retrieval-based concept mapping has shown promise in enhancing long-term memory. Research by Castro Hernandez and Sebrechts (2025) highlights the benefits of retrieval-based learning, particularly through testing, but notes that concept mapping's utility as an alternative retrieval technique is less clear. A study by Bae et al. (2019) sheds light on this by comparing various retrieval-based strategies, including free recall, practice quizzing, test generation, and keyword methods. Their findings indicate a significant interaction between learning conditions and retrieval strategy types. Specifically, free recall and practice quizzing emerged as the most effective retrieval practices. Moreover, combining test generation and practice quizzing with free recall yielded substantial performance benefits. These findings suggest that incorporating retrieval-based strategies, particularly those involving free recall and practice quizzing, can significantly enhance learning outcomes. By integrating these approaches into educational practices, educators can potentially improve students' ability to retain and apply knowledge over time.

Research highlights the significance of conceptual understanding in physics learning, as it supports students' thinking skills and maximizes learning outcomes (Putri et al., 2024). However, studies show that students often struggle with conceptual understanding, particularly on topics like Newton's law of motion. Putri et al. (2024) found that students' conceptual understanding of Newton's law of motion is generally low, indicating a need for improved teaching approaches.

The way physics is taught can significantly impact students' conceptual understanding. Said (2022) discovered a notable difference in understanding between students taught using qualitative versus quantitative methods. The study revealed that an overemphasis on mathematical formulations can hinder qualitative comprehension of physical concepts. Students tend to focus on numerical problem-solving and equation manipulation, often neglecting the

qualitative aspects of physics. This suggests that teaching approaches that prioritize conceptual understanding over mathematical manipulation can lead to better comprehension of physics concepts.

The presentation of information plays a crucial role in determining recall and understanding. Two studies, Lee and Lee (2021) and Zhang and Fukumoto (2023), offer contrasting perspectives on the most effective methods for improving recall. Lee and Lee found that presenting science news content in infographics, as opposed to text, led to improved recall, increased elaboration of message-relevant thoughts, and more favorable attitude changes toward genetically modified foods. This suggests that visual aids can be a powerful tool for enhancing recall and engagement.

In contrast, Zhang and Fukumoto (2023) propose utilizing neural classification models to improve the recall of rough abstract retrieval stages. This approach focuses on optimizing the retrieval process rather than the presentation of information. While Lee and Lee (2021) emphasize the importance of visual aids, Zhang and Fukumoto (2023) highlight the potential benefits of leveraging neural classification models. Despite their differing approaches, both studies acknowledge the importance of improving recall. Lee and Lee (2021) and Zhang and Fukumoto (2023) agree that recall is a critical aspect of understanding and learning, and that optimizing recall can have significant benefits for education and communication. The findings of these studies have important implications for teachers and communicators. By incorporating visual aids, such as infographics, and leveraging neural classification models, teachers and communicators can create more effective learning materials and improve recall. Ultimately, an understanding of the complex factors influencing recall is essential for developing evidence-based strategies to enhance learning and communication.

Research has highlighted the importance of visual aids like virtual laboratories (Darman et al., 2024; Esguerra et al., 2025; Hamed & Aljanazrah, 2020; Mahsuda et al., 2023; Ranjan, 2017; Villada Castillo et al., 2025) and retrieval strategies (Karpicke & Roediger III, 2008; Moreira et al., 2019; Zhang & Fukumoto, 2023) in facilitating learning and understanding. Visual aids, such as knowledge maps (Anastasiou et al., 2024; Lambiotte & Dansereau, 1992), have been shown to enhance recall and understanding, particularly for learners with low prior knowledge. However, the use of metaphors in technical texts may not always facilitate recall and may even lead to superficial processing. Retrieval has been identified as a critical component of learning, with research demonstrating that optimizing retrieval tasks can enhance educational outcomes. Elaborative strategies, such as prompted recall, have been found to promote deeper understanding and better comprehension scores. Theoretical perspectives, including dual-coding theory and the CRH, provide insight into the cognitive mechanisms underlying learning and highlight the importance of designing instructional tasks that promote active elaboration and retrieval.

This conceptual paper makes a significant contribution to the field of physics education by elucidating the interplay between recall and understanding, specifically in the context of Newton's laws of motion. By applying the generate-recognize theory, the paper provides a comprehensive framework for understanding how students encode, store, and retrieve knowledge. It highlights the importance of hands-on experiments and visual aids in enhancing both recall and understanding, thereby offering practical insights for instructional design. The paper argues for prioritizing understanding as the primary goal of education, emphasizing the need for teaching practices that foster critical thinking, problem-solving, and the application of knowledge. By bridging theoretical concepts with practical teaching strategies, this paper aims to inform and improve educational practices, ultimately promoting deeper and more meaningful learning outcomes in physics.

GENERATE-RECOGNIZE THEORY

Since its beginnings, the generate-recognize theory–a well-known framework in memory research–has undergone significant change because to the contributions of important scholars like Kintsch (1968), Bahrick (1970), and Anderson and Bower (1974). This theoretical framework offers important insights into the cognitive processes involved in learning and remembering Newton's equations of motion. It was initially created in the context of word-list research. The generate-recognize theory's central claim is that there is a permanent, atomistic knowledge system made up of distinct concepts or ideas, some of which have word labels. The knowledge system is altered when pupils come across the formulations of Newton's laws, according to the memory trace for that encounter. In particular, the laws' representations are automatically accessible upon contact, and each law's representation is tagged with an occurrence (Bahrick, 1970; Kintsch, 1968).

The idea of mental associationism, which contends that associations between concepts and ideas are essential to memory processes, is also incorporated into the theory (Anderson & Bower, 1974). This indicates that understanding Newton's laws entails coming up with potential uses or situations in which they might be applicable, then identifying and assessing these situations in light of the previously acquired knowledge. The generate-recognize theory is based on the fundamental difference between the processes of generation and recognition. Using their body of knowledge, students generate a set of potential uses or

theories regarding Newton's laws during the generation stage. Students can choose the appropriate application or retrieve the needed information at the recognition stage when these generated hypotheses are assessed and confirmed against the knowledge that has been stored (Anderson & Bower, 1974). This two-step procedure offers a thorough framework for understanding the mechanics behind physics' memory recall and comprehension. Teachers can create teaching strategies that improve students' recollection and comprehension of Newton's laws by utilizing the generate-recognize theory. For instance, assignments that push students to come up with and identify real-world applications of Newton's principles might promote deeper cognitive processing and more significant learning results.

NEWTON'S LAWS AND EXPERIMENTS

Since Newton's laws of motion lay the foundation for subsequent study in physics and other scientific fields, mastering them is crucial for students to succeed in science classes (Gholam, 2019). For students to grasp increasingly difficult ideas in advanced scientific classes and get a thorough comprehension of the natural world, they must have a firm grasp of these foundational ideas. But without a firm grasp of Newton's laws, students might find it difficult to keep up with their classmates in science classes, understand increasingly complex scientific ideas, and eventually have fewer opportunities to excel in science, technology, engineering, and mathematics fields.

In physics, Newton's laws are essential and serve as the foundation for further knowledge. But students frequently have misconceptions (Kibirige, 2022; Maryani & Atmojo, 2024; Sari et al., 2024; Suhandi et al., 2025; Suwasono et al., 2023) that impede their comprehension and development. Concerning statistics from a recent study by Mustofa et al. (2024) show how important it is to evaluate students' prior knowledge of Newton's laws: 53.33% of respondents showed a lack of knowledge, and 40% of respondents came into the study with misconceptions. These results highlight the necessity for educators to recognize and correct students' errors, provide focused teaching methods to close knowledge gaps, and promote a deeper comprehension of Newton's laws.

Research suggests that prioritizing comprehension and memory can be beneficial for students to overcome challenges and achieve academic success in physics. Unlocking Newton's laws and laying a solid foundation for future physics education require this. Teachers may deliver effective instruction, encourage a deeper comprehension of basic concepts, and ultimately put students on the path to success in science education by realizing the significance of clearing up misconceptions and knowledge gaps.

Studies by Snetinová et al. (2018) and Syuhendri (2022) demonstrate that interactive experiments and conceptual change approaches can significantly improve students' conceptual understanding. Syuhendri's (2022) quasi-experimental study found a notable difference in students' understanding between those taught using a conceptual change approach and those taught conventionally. In addition to hands-on experiments, building on personal experiences can also enhance students' understanding of Newton's first law. Students can relate to experiences like tumbling when their skateboard or bicycle comes to an abrupt stop or feeling the force of a seatbelt when brakes are applied (Roemmele & Sederberg, 2017). These experiences illustrate the concept of inertia and help students develop a deeper understanding of the law. By connecting experiments to real-life experiences, students can strengthen their comprehension of Newton's first law.

Snetinová et al. (2018) show that engaging in experiments provides students with a unique opportunity to develop a deeper understanding of fundamental concepts. Newton's law states that an object at rest remains at rest, and an object in motion remains in motion, unless acted upon by an external force. Hands-on experiments, such as rolling a marble or ball on a flat surface, allow students to challenge preexisting assumptions and develop new ones, refining their knowledge system. For example, students may assume a rolling marble will keep moving endlessly, but the experiment demonstrates that frictional forces eventually cause it to slow down.

The importance of hands-on investigation is further emphasized by Newton's own experiments, such as the bucket experiment, which demonstrates the value of experimentation in understanding complex concepts like rotational motion. Contemporary views on physics education highlight the need for students to develop conceptual understanding of physics phenomena (Carpendale & Cooper, 2021). By combining experiments, real-life experiences, and conceptual understanding, students can develop an understanding of scientific concepts.

Hands-on experiments (Snetinová et al., 2018) and computer simulations (Alabidi et al., 2023) are essential tools for students to grasp the intricate relationship between force, mass, and acceleration, as described by Newton's second law. By conducting experiments such as measuring the force required to accelerate objects of varying masses using a spring scale, creating force-motion graphs, and designing simulations, students can generate and test hypotheses, ultimately refining their understanding of the subject (Ha & Kim, 2020). This experiential learning approach enables students to develop a deeper comprehension of the fundamental concepts and their interconnections.

Research has shown that open laboratory activities, where students are encouraged to think reflectively, can lead to an understanding of scientific principles. For instance, students who designed experiments to account for friction and other errors in a Newton's second law experiment developed a more realistic understanding of the law's applications (Ha & Kim, 2020). Moreover, experiments can be designed to test the proportionality of force and acceleration in Newton's second law, even in extreme conditions, such as small forces and accelerations (Gundlach et al., 2007). Incorporating computer simulations into inquiry-based learning environments can also significantly enhance students' understanding of Newton's second law. Studies have demonstrated that computer simulations can promote conceptual and procedural performance gains, particularly when used in conjunction with practical activities, problem-solving exercises, or group discussions (Alabidi et al., 2023). By leveraging both hands-on experiments and computer simulations, educators can create a supportive learning environment that fosters critical thinking, problem-solving abilities, and a deeper understanding of scientific concepts.

In a similar vein, students must do practical experiments in order to fully understand Newton's third law, which states that every action has an equal and opposite response. Students can develop and evaluate ideas by carrying out experiments like launching balloons or rockets, setting up tug-of-war scenarios, or demonstrating reaction forces with skateboards or carts. This helps them to improve their knowledge system. Students' understanding of scientific topics and their applications is strengthened by this experiential learning technique, which helps them to grasp fundamental ideas and their connections. The brain looks for pertinent information and generates possible answers or theories during the generation stage. This could entail formulating theories on motion and physics in relation to Newton's laws. In the recognition stage, these hypotheses are assessed and validated, and their accuracy is verified by comparing patterns with previously acquired knowledge. But according to research, students frequently have trouble understanding physics' causal reasoning, especially when it comes to Newton's third law. After teaching, many students continue to believe that interaction force pairs have a causal relationship, which results in fragmented conceptual understanding, according to a study by Chen et al. (2021). This demonstrates the necessity of focused education and study to dispel these myths.

Additionally, Ding et al. (2024) stress the significance of conceptual transformation in science education, when students switch from employing non-scientific viewpoints to scientific ones. In order to investigate how students' conceptual concepts change throughout this process, their study integrated knowledge integration and model analysis. Prior studies have demonstrated that students frequently have misconceptions regarding Newton's third law, especially when it comes to gravity interaction scenarios (Zhou et al., 2015). This study made clear that in order to overcome these challenges, specialized training and evaluation are required. Teachers can assist students better understand Newton's third law and advance their scientific knowledge and applications by combining practical experiments, generative learning, and causal reasoning.

According to constructivist learning theory, students build new knowledge by connecting it to prior experiences and actively engaging with phenomena (Spiro, 2025). For instance, experiments like rolling a marble down an inclined plane allow students to observe the relationship between force, mass, and acceleration while formulating and testing hypotheses. Research supports the effectiveness of hands-on learning in science education. Studies by Ferrarelli and Iocchi (2021) and Oliveira and Bonito (2023) demonstrate that interactive experiments, including programming mobile robots, improve students' grasp of Newton's laws, academic performance, critical thinking, and problem-solving skills. A recent study also found that students preferred learning models that included practical experiments, with 61.2% of high school students favoring this approach, which combines observing phenomena with hands-on practice (Putra Prima et al., 2024). Cognitive science also suggests that learning is more effective when students process information through multiple modalities–visual, kinesthetic, and verbal (Spiro, 2025). Through discussion and reflection on experimental outcomes, students refine their mental models, correct misconceptions, and develop a more coherent scientific understanding.

The benefits of hands-on experiments are further supported by research showing that interactive engagement methods yield higher learning gains in physics (Hake, 1998; Yeni, 2025). By integrating hands-on experiments with theoretical instruction, teachers can foster meaningful learning outcomes and align with best practices in science education. Inquiry-based activities that encourage exploration, collaboration, and critical thinking can support conceptual development and improve students' ability to recall and apply Newton's laws.

UNDERSTANDING NEWTON'S LAWS

The force concept inventory (FCI) has been widely used to assess students' conceptual understanding of Newton's laws of motion. Thornton and Sokoloff (1998) introduced the force and motion conceptual evaluation, a research-based multiple-choice assessment that evaluates student understanding of dynamics concepts. Their study demonstrated the test's validity and showed that students taught using research-based active

learning strategies, supported by microcomputer-based tools, exhibited significantly improved conceptual learning.

Similarly, Prada Núñez et al. (2022) used the FCI to determine the level of conceptual knowledge of students about mechanical physics and evaluate the effectiveness of different teaching strategies. The test results informed the development of workshops based on real physical situations, which required the elaboration of force diagrams. The study showed evidence of conceptual evolution among students and provided valuable information for future teaching activities on Newton's laws. However, misconceptions about force and motion are prevalent among students. Kibirige (2022) found that 81.8% of grade 11 learners had misconceptions about force, categorized into seven areas. The study used a quasi-experimental design to compare the effectiveness of flipped classes and traditional "talk and chalk" methods. The results showed that flipped classes minimized misconceptions and created interest in science for both high- and low-ability learners, leading to improved performance. The study highlights the importance of innovative teaching strategies in addressing students' misconceptions and promoting conceptual understanding.

Overall, these studies demonstrate the importance of using research-based assessments like the FCI to evaluate student understanding and inform teaching practices. By identifying areas of misconception and using effective teaching strategies, educators can promote deeper conceptual learning and improve student performance in physics. Evaluating students' conceptual understanding is essential to pinpoint their comprehension levels, ranging from genuine understanding to uncertainty, misconceptions, and knowledge gaps (Lisa et al., 2021). This assessment enables teachers to craft tailored interventions for individual students. Notably, Lisa et al. (2021) employed Edupark-based test instruments to gauge students' grasp of Newton's law concepts within the context of the flying fox ride at Bukik Chinangkiek Edupark. Their findings indicated that only 17.83% of students demonstrated a solid understanding, while 3.33% were uncertain, 45.33% harbored misconceptions, and 33.50% lacked understanding altogether.

Newton's second law, for instance, which states that force equals mass times acceleration ($F = ma$), is fundamental to physics, but studies show that students frequently have trouble conceptualizing it (Gates, 2014). Understanding the link between force, mass, and acceleration as well as the proportionality principle–which states that an object's acceleration is directly proportionate to the force applied–is necessary to fully understand this law. For example, the acceleration will double if the force doubles. Furthermore, it is essential to understand that an object's resistance to changes in motion is determined by its mass, a constant attribute. Understanding can be improved by applying this equation to actual situations, like a baseball player hitting a ball or a car accelerating from rest. Important relationships between force, mass, and acceleration can also be found by mathematical modeling with the equation $F = ma$ and by examining force, mass, and acceleration graphs. A complete comprehension of the subject also requires an awareness of the connections between Newton's second law and other ideas like momentum, energy, and work, in addition to Newton's first law. Notably, studies have revealed that students frequently think forces that cause rotational motion have less of an impact on translational motion (Close et al., 2013). This underscores the need for focused educational strategies to dispel such myths and enhance students' qualitative comprehension of force and motion.

A few fundamental ideas must be understood in order to understand Newton's third law, which states that there is an equal and opposite reaction to every action. Fundamentally, the law explains how forces between things reciprocal are. Forces are interactions rather than discrete events, as demonstrated by the fact that whenever object A applies a force to object B, object B always applies an equal and opposite force to object A. Reciprocity, which acknowledges that action and reaction forces act on distinct objects and are always equal in size and opposite in direction, is essential in this situation. The conservation of momentum, which asserts that the overall momentum of a closed system stays constant, is strongly related to this concept and directly leads to the third law.

Nonetheless, research indicates that students frequently have difficulties in gaining a thorough comprehension of this idea. The dynamics of student learning are highlighted by research by Clark et al. (2010), which demonstrates that although direct instruction can be beneficial, concept recall and application can be difficult. Bao and Fritchman (2021) go on to list common problems with student comprehension, such as a lack of connection between causal reasoning and the temporal order of occurrences, the use of rules that have been committed to memory, and the association of action-reaction language with causal ideas. These results point to the necessity of creative teaching strategies. Building PET bottle rockets, as suggested by Correa and Rafaela (2025), is one practical application that effectively improves knowledge. Through direct observation of forces at work, this method helps pupils internalize ideas and develop knowledge more effectively. Students can gain a deeper understanding by applying Newton's third law to real-world scenarios, such as swimming, car acceleration, or rockets. Analysis can also be aided by mathematical representations such as free-body diagrams. Understanding how the third law relates to other ideas such as momentum, energy, and Newton's

first and second laws adds important background information and enhances comprehension.

VIRTUALIZATION OF NEWTON'S LAWS

The integration of virtual laboratories (Darman et al., 2024; Esguerra et al., 2025; Hamed & Aljanazrah, 2020; Mahsuda et al., 2023; Ranjan, 2017; Villada Castillo et al., 2025) in science education has been shown to significantly enhance students' understanding and skills in various scientific disciplines. Research by Esguerra et al. (2025) demonstrates that virtual laboratory applications, when combined with guided inquiry activities, enable students to break down complex concepts into simpler, more manageable components. This approach allows learners to grasp procedural activities more easily, leading to improved comprehension of scientific principles. Furthermore, studies such as the one conducted by Hamed and Aljanazrah (2020) highlight the effectiveness of virtual experiments in deepening students' understanding of physics concepts. Their findings suggest that students who utilize virtual components are better prepared to conduct real experiments, and online resources provide a more flexible and enriching learning environment. Additional research by Ranjan (2017) supports the use of virtual laboratories in physics education, particularly for visualization and graphical representation. This study underscores the potential of virtual labs to enhance conceptual understanding and skill development in physics.

Overall, the evidence suggests that incorporating virtual laboratories into science education can have a positive impact on student learning outcomes. By leveraging virtual labs, educators can create more engaging, effective, and flexible learning environments that cater to diverse student needs. The application of simulations in teaching Newton's laws finds substantial support within the realm of physics education, with researchers like Almadrones and Tadifa (2024) positing that simulations can engender positive and engaging learning experiences. Furthermore, Pranata's (2024) research underscores the efficacy of physics education technology simulations in augmenting students' grasp of vector operations, illustrating the significant enhancement simulations bring to understanding complex scientific notions. These findings affirm the value of simulations as a potent instrument in physics education, facilitating comprehension of intricate concepts.

Beyond simulation-based learning, virtualization enables robust visualization and modeling capabilities that can significantly bolster students' understanding of complex concepts. Through 3D modeling, students can craft and manipulate virtual objects, thereby visualizing force vectors and motion trajectories with greater clarity. Complementing this, data visualization tools empower students to analyze and visualize data more effectively, rendering the relationships between forces, masses, and accelerations more palpable and accessible. Virtualization also unlocks avenues for gamification and heightened engagement, rendering the learning of Newton's laws an enjoyable and captivating pursuit. Interactive games and challenges have the potential to elevate student motivation and participation, while virtual environments facilitate collaborative learning, wherein students can conjointly engage with simulations and experiments, nurturing peer-to-peer learning and discourse. Recent research highlights the potential of innovative approaches to enhance student learning outcomes in physics education. A study by Richter and Kickmeier-Rust (2025) demonstrates the effectiveness of gamification in boosting student engagement, motivation, and performance in physics. By leveraging structural performance modeling through knowledge space theory, gamification significantly increased time on task, attempt frequency, and scores, underscoring its potential to improve learning outcomes. Another study by Villada Castillo et al. (2025) explores the efficacy of serious games in immersive virtual reality environments for physics learning. The findings reveal significant improvements in theoretical understanding and practical application of complex scientific concepts, emphasizing the importance of aligning educational content with interactive gameplay. This research suggests that well-designed serious games can be a valuable tool in physics education, providing a promising approach for future educational strategies in scientific disciplines. These studies collectively suggest that integrating innovative approaches like gamification and serious games into physics education can have a positive impact on student learning outcomes. By harnessing the potential of these tools, educators can create more engaging, effective, and interactive learning environments that enhance student understanding and application of complex scientific concepts.

Virtualization also offers benefits in terms of accessibility and flexibility. Remote access to simulations and experiments can enable students to learn Newton's laws anywhere, anytime, while personalized learning paths can allow students to learn at their own pace and focus on areas where they need improvement. Finally, virtualization can facilitate assessment and evaluation, providing immediate feedback and enabling instructors to track student progress and understanding of Newton's laws. By leveraging virtualization, teachers can create immersive and interactive learning experiences that enhance student engagement, understanding, and recall of Newton's laws. The virtualization of Newton's laws offers significant advantages for modern physics education. According to Mahsuda et al. (2023), virtual science has become an essential tool for scientific research in the 21st century. This is further supported by Darman et al. (2024), who

highlight the innovative design of virtual laboratories and their positive impact on learning activities. The application of virtual labs can enhance various educational outcomes, including creativity, problem-solving, critical thinking, and learning independence. Additionally, virtual labs improve science literacy skills, inquiry activities, conceptual understanding, and the reconstruction of scientific concepts. They also enhance graphic interpretation skills, science process skills, mastery of concepts, academic achievement, students' physics competence, and communication skills. By integrating virtual labs into the teaching of Newton's laws, teachers can create a dynamic and interactive learning environment that fosters deeper understanding and retention of these fundamental principles.

CONCLUSION

The connections between recall and understanding in the context of Newton's laws have been explored in this conceptual paper. The analysis suggests that recall and understanding are distinct cognitive processes that contribute to meaningful physics learning. The relationship between recall and understanding has implications for teaching and learning strategies related to Newton's laws. By recognizing the role of recall as a foundational element, educators can design lessons that prioritize depth of understanding. This paper highlights the importance of exploring innovative approaches, such as gamification and virtualization, that may enhance both recall and understanding in physics education.

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