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EXPLORING STUDENTS' CONCEPTUAL UNDERSTANDING OF NEWTON'S LAWS: FINDINGS AND ANALYSIS BASED ON CONCEPTUAL TESTS

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Abstract :
The ability to think critically and solve complex problems requires a deep understanding of physics concepts. This study employed a novel method to conduct a multidimensional analysis of students' conceptual understanding of Newton's Laws using conceptual tests designed to assess indicators of interpretation, exemplification, inference, comparison, explanation, and integration. This study addresses conceptual understanding as a whole and in a controlled manner, and the action learning approach can support it. The sample in this study consisted of 25 students of class XII 1 at a high school in Kupang City, NTT. This study used a quantitative, descriptive, cross-sectional approach. The results showed that the average understanding score of students as a whole was in the "very low" category, namely 28.4%. Two main weaknesses were also found in students: (1) students showed a better understanding of Newton's First Law compared to the Second Law (29.6%) and the Third Law (22.4%), which were more applicable, and (2) "Comparing" was the lowest indicator (21%). Meanwhile, by gender, female students excelled in the "inferencing" indicator, while male students excelled in the "exemplifying" indicator. The results of this study indicate that learning methods that primarily focus on lectures and abstract physics concepts can hinder conceptual understanding and analytical and comparative skills. Therefore, this study recommends implementing an experiment-based learning approach to improve students' practical experience and conceptual understanding, and to relate it to analytical indicators and Newton's Second and Third Laws.

Keywords: Concept Understanding; Newton's Laws; Misconceptions

INTRODUCTION

Understanding concepts is a crucial part of learning physics, as it is essential for developing students' higher-order thinking skills (Docktor & Mestre, 2014; Shishigu, 2018; Putranta & Pahar, 2019). Newton's Laws of Motion are fundamental to physics and often confuse students. Numerous studies have shown that students struggle to understand the basic concepts of Newton's Laws and their application to everyday situations, even though they have been exposed to the topic since junior high school (Fathurohma et al., 2021; Asakle & Barak, 2022). Earlier studies found that many students still hold misconceptions about force and motion concepts (Sari et al., 2019; Khoirunnisa & Afifa, 2024; Saputra & Rusyati, 2025). These misconceptions are hard to change because they stem from everyday ideas that students already believe are correct, even when they do not align with scientific thinking (Capriconia & Mufit, 2022; Kotsis, 2023).

A good understanding of Newton's Laws is very important, not only for school purposes, but also because it can help students understand and explain more difficult physics concepts in their studies (Alabidi et al., 2023; Isra & Mufit, 2023; Suwasono et al., 2023). Physics lessons that focus too much on routine tasks ignore students' actual needs, such as a more profound, more precise understanding of physics concepts. (Sirnoorka et al., 2023; Dessie, 2023; Sitopu et al., 2024). As a result, students might be good at calculations but still struggle to understand real-world situations, explain daily events, or apply their knowledge in new contexts.

To address these challenges, the study aims to determine students' conceptual understanding of Newton's Laws using a concept test adapted from (Furqon, 2019). Previous research has focused on identifying students' misconceptions or examining the overall results of student comprehension tests on Newton's Laws. However, few studies have provided a clear picture of a detailed diagnostic profile and linked it to specific cognitive indicators or sub-topics. Therefore, this study contributes to providing a multidimensional analysis of students' conceptual understanding of Newton's Laws. This study integrates indicators of students' cognitive understanding of Newton's Laws and their understanding of the three main sub-topics of Newton's Laws. It examines differences between male and female students. This study enables teachers to identify the learning difficulties students face in Newton's Laws and to design learning strategies that are appropriate to students' needs and more focused. This is expected to assist teachers in transmitting learning outcomes and designing more effective process strategies.

These days, science education in many countries puts more emphasis on helping students build solid conceptual understanding and the ability to reason scientifically. (Malone, 2023; Mi et al., 2020; Mulyani et al., 2023), further underscoring the relevance of this research. Students' critical thinking and problem-solving skills are increasingly in demand, and a deep understanding of fundamental physics concepts, such as Newton's Laws, is crucial. This research aligns with educational demands to encourage meaningful learning and reduce physics learning that relies solely on rote memorization without a deep understanding of concepts. (Abeden & Siew, 2022; Dzaiy & Abdulla, 2024).

Based on the background that has been explained previously, several research problem formulations can be formulated: (1) What is the level of students' conceptual understanding of Newton's Laws in general? (2) How is the distribution of students' correct answers based on the level of difficulty of the questions in various aspects of Newton's Laws? (3) What is the level of students' conceptual understanding in each sub-concept of Newton's Laws? (4) How is students' conceptual understanding in each indicator of conceptual understanding? Moreover, (5) Are there significant differences in conceptual understanding between male and female students? These questions are very important considering the findings of Singh and Singh and Wandi et al. (2023) That conceptual understanding in physics often varies with the complexity of the material and students' demographic characteristics. This research is expected to make a distinct contribution by providing a multidimensional analysis of students' conceptual understanding of Newton's Laws and their sub-materials, and by integrating cognitive indicators, sub-concept components of Newton's Laws, and gender-based differences.

RESEARCH METHOD

Research Design

This study uses a quantitative descriptive research design with a cross-sectional approach. A cross-sectional design is a type of research that collects data at a specific point in time or in a short period of time (Sukmawati et al., 2024). The main purpose of this design is to describe or analyze the relationship between various variables in the population being studied at a particular time (Johnson & Christensen, 2019; Creswell & Creswell, 2022). In this study, the focus is on analyzing students' conceptual understanding of Newton's Law based on the number of correct answers on the test, as well as the distribution of students' responses to the test questions.

Research Target/Subject

The population in this study consisted of 25 students in class XII IPA at one of the public high schools in Kupang City, 18 female and seven male. These students were selected because they had studied Newton's Law as part of the high school physics curriculum. The sample size of 25 students was considered adequate to represent a range of conceptual understanding in introductory physics. The selection of 25 12th-grade science students as subjects for this study was tailored to the needs of the initial diagnostic study. While the sample size is small, it falls within the recommended range for preliminary research, around 10–30 students, as reported in some literature (Johanson & Brooks, 2010; Sukserm, 2024). The goal is to gather sufficient baseline data to examine average-value patterns and identify weaknesses in certain concepts without requiring a large sample size. This initial data can then be used to design broader interventions.

Research Procedure

In this study, the conceptual understanding test was administered using Google Forms. Google Forms was chosen primarily because it is easy to access, allowing students to take the test on their computers or mobile phones without much difficulty. The use of online tests is also increasingly common in physics education research, primarily because the data collection process is more efficient and student responses can be recorded in a relatively natural manner.

Instruments and Data Collection Techniques

This study used a conceptual understanding test instrument consisting of 20 questions on Newton's Laws, adapted from Furqon (2019), specifically measuring Newton's Laws. This instrument has been tested and validated (Content Validation Ratio—CVR) with a result of 1.00; this result is sufficient to indicate that the questions on this instrument are highly relevant to the material being tested and can be used for this study. This instrument also demonstrates adequate internal reliability, as indicated by the Kuder-Richardson 20 (KR-20) coefficient of 0.673. This reliability value is considered acceptable for exploratory research and preliminary studies that aim to provide an initial assessment of concept mastery. Conceptual tests are widely used in Newton’s Laws research because they allow researchers to identify both surface-level and deep-level reasoning. The question matrix for the student concept understanding test is shown in Table 1.

Table 1. Comprehension test instrument grid

Aspects of understanding ability	Question item	Sub-material	Subconcept	Question item
Interpreting	1, 2, 3, 4	Newton's First Law	Inertia	5, 17
			The relationship between mass and inertia	1, 9, 13
Exemplifying	5, 6, 7, 8	Newton's Second Law	The relationship between force and acceleration	2, 6, 7, 10, 14, 18
			The relationship between mass and acceleration	3, 11, 15, 19
Inferencing	9, 10, 11, 12	Newton's Third Law	The relationship between action force and reaction force	4, 8, 12, 16, 20
Comparing	13, 14, 15, 16,	-	-	
Explaining	17, 18, 19, 20	-	-	

Furqon (2019)

The rubric for assessing understanding of Newton’s Laws is shown in Table 2.

Table 2. Rubric for assessing students' understanding of newton's law material

Answer	Score
True	1
False	0

Data Analysis Technique

The data obtained from the concept understanding test were analyzed using quantitative descriptive analysis. The percentage of each student’s score was calculated using the following formula:

$$NS = \frac{n}{SM} \times 100\% \qquad (1)$$

Description:
NS: Student score
N: Score obtained by students
SM: Maximum score of the test in question
Furthermore, the average value of understanding the concept is interpreted in the following table:

Table 3. Interpretation of the concept understanding ability score

Score	Criteria
85,00 – 100	Excellent
70,00 – 84,99	Good
55,00 – 69,99	Satisfactory
40,00 – 54,99	Low
0,00 – 39,99	Very low

RESULTS AND DISCUSSION

In this section, the results of the analysis of students' conceptual understanding of Newton's Laws material will be presented, obtained from the concept understanding test administered. This aims to provide a clearer picture of students' understanding of Newton's Laws material, and the results will be presented to show students' overall conceptual understanding and the distribution of their scores across each indicator of conceptual understanding. The results obtained are expected to identify the general trends and variations in students' understanding of Newton's Laws.

First, the results of this study will present descriptive statistics summarizing all findings from the student concept understanding test. These results can be presented in Table 4, the descriptive statistics of student concept understanding, where this data will be used as an important reference to identify further findings on indicators of student conceptual understanding in the material of Newton's Laws, so that it can be seen which have truly been mastered well by students and which require further improvement and necessary follow-up.

Table 4. Descriptive statistics of students' concept understanding

Descriptive Statistics									
	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Nilai	25	65.00	5.00	70.00	710.00	28.4000	3.05123	15.25615	232.750
Valid N (listwise)	25								

Based on the results in Table 4, the total score is 710 across 25 students. Also obtained is the average understanding of student concepts, 28.4. Based on the Table 3 criteria for understanding the concept, the average score falls within the range 0.00-39.99, indicating very low criteria. Research conducted by Sahara (2019) showed that, of 56 students, 38.71% understood Newton's law well, 39.07% had misconceptions, 11.21% partially understood or were undecided, and 11.00% did not know the concept at all. Following these findings, it is important to analyze further how the distribution of students' correct answers, based on items that show the relative difficulty of various aspects of Newton's Law, as shown in Figure 1, will be discussed in the following section.

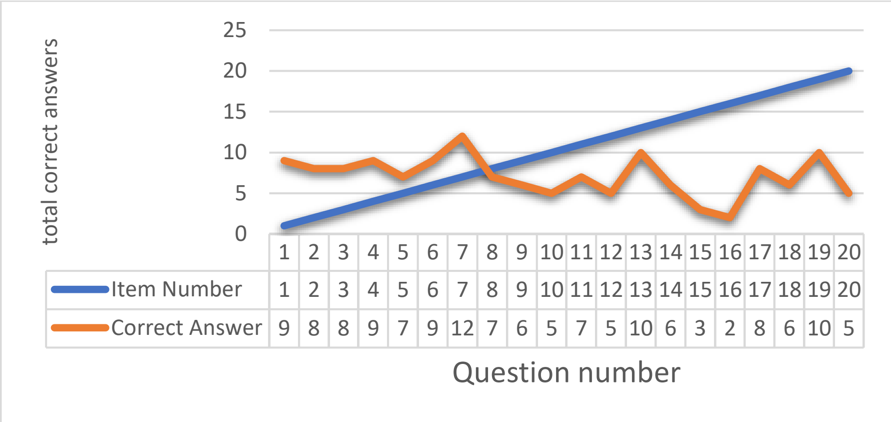

Figure 1. Number of correct answers by item

This figure shows the distribution of students' correct answers to 20 items. The number of correct answers varies significantly, ranging from 2 in question 16 to 12 in question 7. In general, questions with a high success rate, such as number 7, indicate that the concept tested by the question is relatively easy or well understood by students. Conversely, questions with a low number of correct answers, such as number 15 (3 correct answers) and number 16 (2 correct answers), indicate that the related concepts remain complex for most students. This difficulty is particular, as question number 15 tested the ‘Comparing’ indicator on the relationship between mass and acceleration (Newton's Second Law), and question number 16 tested the ‘Comparing’ indicator on action-reaction forces (Newton’s Third Law). These results are consistent with previous studies, according to Zulfa et al. (2025) It was found that the grade X MIPA students at a Private High School in Malang City have difficulties in the implementation of Newton's Law II and Newton's Law III, and the difficulty experienced by students on the second indicator (Newton's Third Law) is that students explain that mass affects the interaction of forces. This shows that students have a misconception about the pair of action and reaction forces.

This kind of analysis is often used to identify areas of weakness in students' concept understanding. The data from this figure shows the importance of structured formative evaluation to improve learning effectiveness. Teachers can use this data to redesign questions or provide specific reinforcement on complex topics. Approaches such as remedial teaching or delivering material using visual media can help students understand concepts that were previously considered difficult (Simamora, 2024; Thote & Gowri, 2020).

After discussing how students' correct answers were distributed by question difficulty, the next step was to examine their understanding of each subconcept of Newton's Law. The results are shown in Figure 2. This analysis is important for understanding how well students understand specific parts of the law. This allows us to more clearly see the difficulties students experience with each subconcept of Newton's Law.

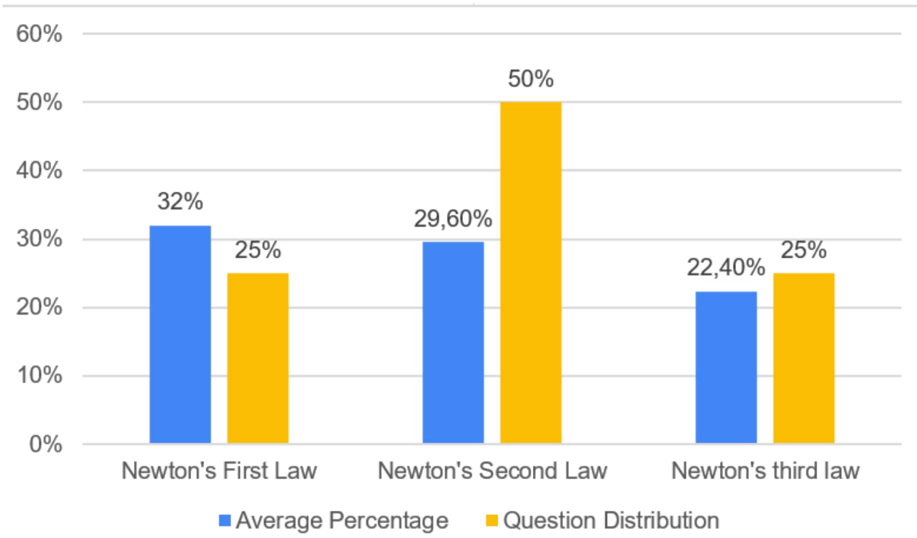

Figure 2. Average concept understanding by sub-concept

As shown in Figure 1, the average score for students' conceptual understanding of Newton's first law was 32%, which is higher than the scores for students in the material on Newton's second law and third law, which were only 29.6% and 22.4%, respectively. Of course, this shows that it turns out that students find it easier to understand Newton's first law, which is basically descriptive and has fewer concepts compared to Newton's second and third laws, where as we know that Newton's second and third laws require more mathematical or applicative understanding, and require students to be able to distinguish several concepts in one sub-material. This finding is supported by previous research, Parra-zeltzer & Huincahue (2025) where he stated that although its formulation seems simple, Newton's second law, which is the core of classical mechanics and important for in-depth understanding in this field, is complex to understand, thus hampering students' ability to apply the concept in various contexts. The low conceptual understanding of Newton's second and third laws of physics may also be due to the lack of variety in the learning methods and models used in schools. Lecture-like methods still dominate physics learning in the field, and of course, this can be one of the reasons why students are less able to understand more abstract and applicable concepts, such as Newton's second and third laws. To overcome this, a breakthrough in physics learning is needed, so that students can better understand the concepts of Newton's laws. As research by Khairat (2024) Revealed that experiment-based learning can help students understand physics concepts, especially Newton's laws. Teachers can consider using simple experimental methods in lectures, such as direct demonstrations of attractive forces or the use of digital simulations (Banda & Nzabahimana, 2021; Susilawati et al., 2022). Of course, this will make learning more meaningful and help students better understand Newton's laws of physics and other abstract physics concepts.

Furthermore, using experiment-based learning can be helpful because students gain hands-on experience as they learn the material. This approach often makes somewhat abstract concepts, such as Newton's Second and Third Laws, more straightforward to grasp (Anisa et al., 2024; Naushabekov et al., 2025). For example, when students conduct experiments on force under different conditions, the relationship between force and motion becomes clearer, something that can be difficult to grasp simply from explanations. Furthermore, digital simulations can also be used. The visualizations generated from simulations often help students connect theory to real-world situations (Nugraha & Kharisma, 2024).

After this, the analysis moves to how students perform on each indicator of concept understanding. The goal is to see to what extent they can understand and master each indicator, as well as which parts still appear weak or need improvement in learning. The results are shown in Figure 3.

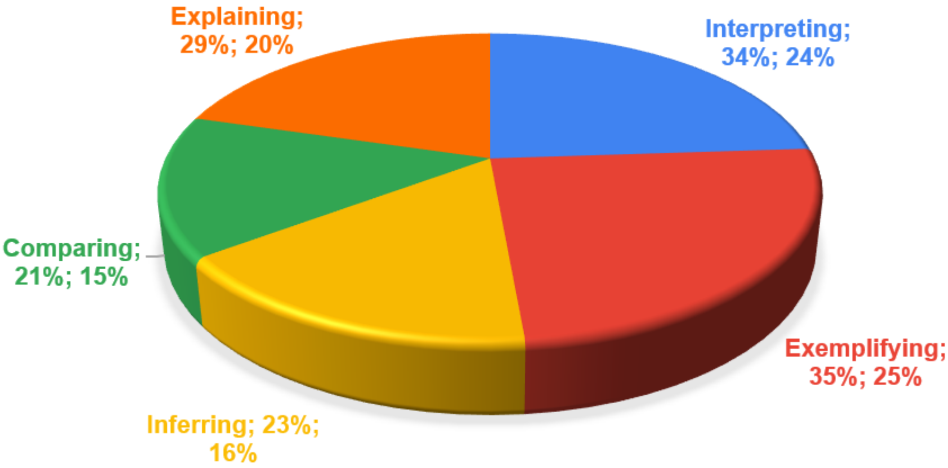

Figure 3. Percentage of concept understanding indicators

In Figure 3, we can see the results showing the level of students' understanding on various indicators of understanding to answer the second research question, where the figure shows the results obtained are the indicator of giving examples gets the highest percentage of 35%, followed by the indicator of interpreting at 34%, then explaining at 29%, and concluding at 21%, and comparing is the indicator with the lowest percentage of 21% with the lowest percentage on "comparing" (21%). We can see that the lowest percentage on the comparison indicator means that students are still less trained in comparing or distinguishing relationships between concepts. As the findings obtained in previous studies, which revealed that among the main difficulties in learning Newton's second law is the confusion between force and velocity, not acceleration, which causes misunderstandings (Parra-zeltzer & Huincahue, 2025). Let us see: this can happen because children are not allowed to engage in activities that make them think more deeply, for example, group discussions in class or assignments that focus on comparing one concept with another. In fact, if we provide them with more analytical-based learning experiences, their critical thinking skills in this area will automatically improve. Therefore, future learning designs must include more tasks involving comparison and reflection. The goal is clear: to strengthen and solidify the connection between concepts and students' analytical reasoning skills.

Using active learning strategies, such as group discussions or problem-solving, can be an alternative solution to improve students' analytical skills (Agustin et al., 2021; Mahfud et al., 2024).. Teachers in schools can begin to incorporate activities that require students to compare certain ideas into learning sessions, for example, asking students to compare how Newton's Laws apply to various real-life situations. This step will certainly help strengthen benchmarks of understanding that have previously been felt to be lacking. Furthermore, including thought-provoking questions and collaboration among students can encourage them to reflect further on the similarities and differences between various physics concepts (Guo et al., 2024; Janjanam, 2025). These learning activities have the dual benefit of deepening conceptual understanding while also stimulating critical thinking skills, which are essential for studying physics.

Furthermore, indicators focused on comparison can be developed by presenting tasks that test students' abilities, asking them to analyze and contrast how Newton's Laws operate in different physical situations or events. These activities can take the form of case studies, hands-on experiments, or group discussions that prompt students to identify similarities and differences among ideas. Furthermore, using technology, such as physics simulations, can provide more immersive experiences and support students' understanding of comparing concepts in more concrete, practical situations. By implementing these more applicable and engaging activities, it is hoped that students' understanding of the comparison indicators and their critical thinking skills in general will improve (Agustiani & Jailani, 2023; Erlina et al., 2021).

For clarity, the examination continued by examining whether students' conceptual understanding differed significantly by gender. The findings from this examination are crucial for uncovering the possible influence of gender on students' grasp of Newton's Laws, as shown in Illustration 4.

The purpose of this comparison was to explore whether male and female students had similar levels of understanding across aspects such as explaining, illustrating, drawing conclusions, and comparing. By examining the average scores for each gender, researchers determined whether there were consistent patterns or apparent differences in specific areas of conceptual mastery. The results of this comparison are expected to provide useful insights into how learning experiences and interest in physics may differ between male and female students.

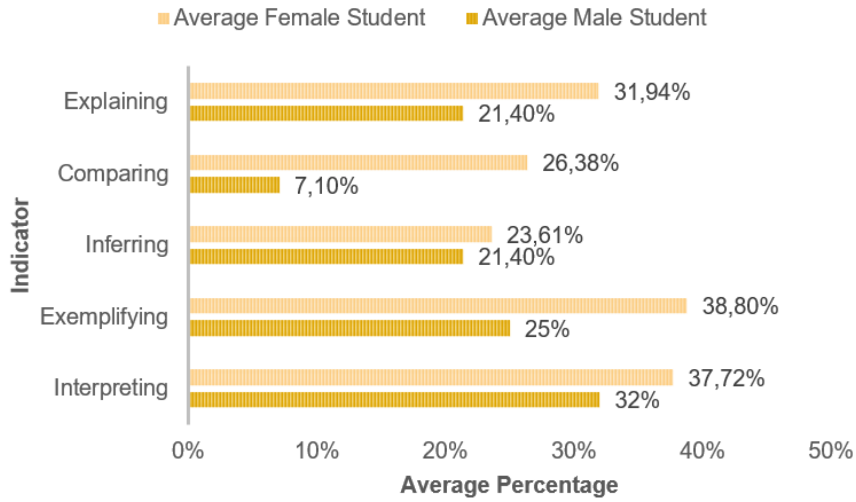

Figure 4. Average indicator of concept understanding based on gender

Based on Figure 4, the data analysis shows that male students performed better on the exemplification indicator, with a score of 38.8%, slightly higher than that of female students, who achieved 37.72%. This indicates that boys are better at providing concrete illustrations that fit the discussion of an idea. Furthermore, they excelled on the comparison indicator, with a score of 23.61%, compared to 21.4% for female students. The ability to compare requires critical thinking about the differences or similarities between concepts, which suggests that male students are more responsive to ways of thinking that involve processes and conceptual frameworks.

On the other hand, female students showed superiority in the inferring indicator with a percentage of 26.38%, compared to male students who reached 23.61%. This indicator relates to the ability to conclude the available data or information. The superiority of female students in this aspect may reflect their tendency to be more careful and reflective in their understanding of the context before concluding. Psychological factors, such as a more emotional and meticulous approach among female students, can improve inference ability (Spinath et al., 2014).

These differences can be influenced by biological, social, and learning experiences that shape students' approach to physics learning. Male students tend to be more confident in answering questions that require hands-on exploration, while female students excel in activities that involve deep understanding (Ro et al., 2022). By understanding this data, teachers can design learning strategies that are inclusive and balance the learning needs of male and female students. For example, project-based activities can be designed to improve the analytical skills of female students, while scenario-based discussion approaches can help improve inference skills in male students ((IBE)-UNESCO, 2017).

The results of this study demonstrate the need for physics instructors to focus more on methods to uncover and address student misconceptions early in the learning process. Using tools to detect conceptual understanding and encourage students to explain the rationale behind their responses could help deepen understanding of Newton's Law. However, this study has several limitations, including a relatively small sample size, limited coverage of Newton's Law, and no comparison or control group to assess the effectiveness of the teaching method. These shortcomings should be taken into account when interpreting the results and could provide a basis for future research with a more comprehensive plan.

CONCLUSION

This research indicates that students' grasp of Newton's Laws remains relatively poor, particularly with the Second and Third Laws, and in thinking skills such as comparison. These problems stem from teaching that is mostly lecture-based and from concepts being hard to picture. Because of this, teachers should try to include simple activities that involve experiments, use computer models or videos to help clarify the ideas, and test students early to identify any misunderstandings. For those doing research later, it is suggested they use more students, use different ways of studying the issue to better understand how students think, and study how well certain teaching methods work, like learning by asking questions or giving support step by step to improve areas students struggle with, such as comparing and giving examples.

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