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RESEARCH ARTICLE

Student Challenges in Understanding Newton's Law: An Analysis Using Isomorphic Multiple-Choice Items

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Abstract

Newton's Law is a basic concept in physics learning at the high school and college levels, but students' conceptual understanding of the concept is still weak. This study aims to analyze students' difficulties in the concept of Newton's Law by looking at the consistency of students' answers to isomorphic problems. The research method used quantitative research by means of a survey. The respondents were 118 students (58 high school students and 60 MAN students) who had taken the Newton's Law chapter. The research instruments were adapted from the Force Concept Inventory (FCI) and isomorphic multiple-choice question (IMCI) which were validated by two physics experts. The analysis technique uses isomorphic analysis by looking at the consistency of student answers to the concept of Newton's Law. Based on the consistency of the answers, three groups of students' conceptual understanding were determined, namely the "Understanding" when students were consistently correct on three isomorphic items, "Moderately Understanding" if they were consistently correct on two isomorphic items, and "Not Understanding" if only one answer was correct or did not answer correctly on the isomorphic items. The study found that students' conceptual understanding on all isomorphic items was low. especially in Theme 5 which is about the concept of analyzing the relationship between force and the speed of motion of objects with 97.46% of students having difficulties, and Theme 3 with the concept of action-reaction on Newton's Third Law with 95.76% having difficulties. The recommendation for further research is to apply learning methods to overcome students' difficulties in Newton's Law.

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INTRODUCTION

Newton's Law is one of the fundamental concepts in physics learning. Various phenomena in everyday life use the concept of force and motion, such as car motion, rocket launching, and even the concept of walking which can be explained by the concept of Newton's Law (Parno et al., 2022; Serhane et al., 2023). In instructional physics, a deep understanding of Newton's Laws prepares students to explore and understand physics disciplines at various levels of education. At the secondary level of education, Newton's Laws play a role in strengthening students' basic understanding of motion dynamics. Through a good understanding of motion dynamics, it will help students understand advanced concepts that are still related to the concept of force, such as buoyancy force, electrostatic force, magnetic force and modern physics (Taqwa et al., 2022). At the university level, Newton's Law is the basis for learning mechanics (Parno et al., 2022). Thus when students have a good understanding at the intermediate level, it will prepare students to learn more complex and abstract concepts in college.

Understanding of Newton's Law helps to a broader scientific knowledge base, however past research, it was found that students experienced difficulties in Newton's Law, such as difficulties in the concept of action-reaction force pairs and difficulties in identifying forces on objects at rest or moving at constant speed (Bouzid et al., 2022; Fazio & Battaglia, 2019; Kusairi et al., 2022). These difficulties often arise due to students' inability to relate abstract concepts to phenomena in everyday life (Handhika et al., 2016). These difficulties will have an impact on students' low conceptual understanding of Newton's Law. Moreover, the low mastery of students' concepts on Newton's Law will also hinder students' process in learning more complex physics (Taqwa et al., 2022; Utami & Nurlaela, 2021). For example, when students cannot identify the forces acting on a stationary object, they will have difficulty in determining the buoyancy force in floating, levitating, and sinking conditions. Therefore, identifying specific difficulties faced by students in Newton's Law not only helps reduce student misconceptions, but also helps build a solid foundation in understanding more complex physics concepts. For this reason, it is important to identify student difficulties in Newton's Law.

Several studies have been done to determine students' conceptual understanding of Newton's Law, and the Force Concept Inventory (FCI) is the most commonly suggested research instrument (Madsen et al., 2019), however the scoring technique widely employed in prior studies is percent correct. The disadvantage of this scoring approach is that it may neglect guessing strategies in students' answers (Iversen, 2016), so it does not always provide an accurate picture of students' conceptual understanding. For example, if a student provides a response based on a guess and it turns out to be correct, the student is judged to have comprehended the subject. Bollen et al. (2016) also revealed that if students understand physics concepts well, then students will remain consistent in answering questions correctly even with different contexts, while if using the percent correct analysis method cannot assess physics understanding consistently. Thus, a simple scoring technique is required for accurately assessing students conceptual understanding. One alternative that can be used is using isomorphic scoring techniques (Kusairi et al., 2022). The scoring technique allows to evaluate students' conceptual understanding based on the consistency of answers to three questions in one theme. Compared to the percent correct scoring technique, the isomorphic scoring technique reduces the possibility of scoring influenced by chance or guessing factors. In addition, in research on mastery of the concept of Newton's Law that has been done before, not many have been able to categorize student mastery, such as the categories of Mastering the Concept, Adequately Mastering the Concept, and Not Mastering the Concept, mostly only in the form of general conclusions stating that students' mastery of concepts is low (Hau & Nuri, 2019; Sandra et al., 2018). By using isomorphic question instruments and isomorphic analysis techniques, student mastery can be categorized based on the consistency of student answers. Thus, the research instrument used was also formed in isomorphic items by combining instruments from FCI and IMCI research. Building on this approach, our research focuses on two crucial questions: how students understanding Newton's Law and what concepts are the most difficult for students to understand.

METHOD

The survey was conducted with the aim of finding out students' difficulties on the topic of Newton's Law. The following is a description of the research design, participants, data collection techniques and research instruments, and data analysis.

Research Design and Procedures

The survey analyzed students' difficulties in Newton's Law using a quantitative approach. The survey was conducted by giving a multiple choice test in the form of a paper test. Respondents will take the test for 45 minutes with close supervision by teachers and researchers. Assessment of student answers uses isomorphic techniques to determine the consistency of student answers.

Population and Sample

There are 6 clusters in senior high schools and 7 clusters in Islamic high schools. In each school, 2 clusters were selected using the cluster random sampling technique. The total number of respondents was 118, taken from two schools: a high school with 58 respondents and an Islamic high school with 60 respondents. All respondents have taken Newton's Law material in physics learning. Furthermore, all respondents have taken other material relating to the interaction of forces, namely buoyancy forces in fluid talks. Respondents at each school received the same number of physics study hours, namely four hours of lessons each week.

Data Collection and Instrument

The research data is quantitative data. Data collection techniques using survey. The research instrument consisted of isomorphic questions with seven Newton's Law concept themes, each of which contained three items. A total of 21 pieces were used. The research instrument was adapted from the FCI established by Hestenes et al. (1992) and the IMCI questions developed by Kusairi et al. (2022). The FCI is a multiple-choice inventory commonly used in physics education research. Meanwhile, IMCI is a test designed to identify student misconceptions in the form of isomorphic multiple choice. The question instrument was validated by two physics experts with aspects of assessment, namely the suitability of the question with the question indicator, and mastery of the concept to be measured, as well as the correctness of the concept in the answer key. The results show that the question instrument is valid to be used to measure students' mastery of concepts on Newton's Law. Data collection was grouped in a total of four classes, with two classes in each school. Data collection time was carried out alternately for each class. Data collection was carried out during effective learning hours. Respondents completed on the research instrument in the form of a paper test for 45 minutes, observed by teachers and researchers. The instrument for conceptual understanding of Newton's Law in detail is described in Table 1 below.

Table 1. Newton's Law Conceptual Understanding Instrument (α=0.644)

Theme	Indicator	Item	Point-Biserial	Difficulty Index	Discrimination Index
T1	Analyze the magnitude of the force acting on an object with constant velocity	1	0.333	0.170	0.173
		8	0.327	0.271	0.136
		15	0.617	0.305	0.465
T2	The effect of force on the acceleration of an object	2	0.379	0.390	0.172
		9	0.650	0.246	0.516
		16	0.620	0.254	0.478
T3	Analyze the magnitude of the action-reaction force on two objects that touch each other	3	0.425	0.229	0.254
		10	0.089	0.085	-0.035
		17	0.221	0.093	0.093
T4	Determine action-reaction force pairs in phenomena	4	0.226	0.271	0.029
		11	0.059	0.186	-0.114
		18	0.099	0.051	0.001
T5	Analyze the relationship between force and the velocity of an object	5	0.028	0.161	-0.135
		12	0.368	0.025	0.305
		19	0.235	0.136	0.084
T6	Analyze the forces acting on an object	6	0.219	0.051	0.123
		13	0.343	0.119	0.207
		20	0.221	0.246	0.030
T7	Analyze the amount of friction force on a stationary object on a rough floor	7	0.184	0.051	0.088
		14	0.267	0.042	0.181
		21	0.140	0.161	-0.023

The biserial points in Table 1 provide information about the extent to which the item is correlated with the respondent's overall performance. Difficulty index provides information about the size of the proportion of respondents answering the item correctly. The discrimination index provides information on the ability of a test item to distinguish between participants with good and poor understanding in answering questions. The question instruments used mostly have biserial points, difficulty index, and discrimination index in good numbers.

Data Analysis

The scoring and analysis technique uses the isomorphic method by looking at the consistency of students correct answers. Students will get two points if they successfully answer all questions correctly in one theme and are classified as understanding the concept, one point if they successfully answer two questions correctly in one theme and are classified as moderately understanding the concept, and zero points if they only answer one question correctly or fail to answer questions correctly in one theme and are classified as not understanding the concept. Calculated the percentage of students who belong to the Understanding Concept, Moderately Understanding Concept, and Not Understanding Concept groups in each theme so that it will appear on what theme or concept students have the lowest concept mastery.

RESULT AND DISCUSSION

Result

Descriptive statistics were conducted on the survey results of 118 respondents. The results of descriptive statistics are described in detail in Table 2.

Table 2. Descriptive Statistics Results

Number of Respondent (N)	118
Minimum Value	0.0
Maximum Value	57.14
Mean	7.02
Standard Deviation	9.43

Table 2 shows that the average students' conceptual understanding on Newton's Law is low with a score of 7.02 out of 100 points. The standard deviation of 9.43 shows that there is a wide spread of data from the average, which indicates that there are significant differences in the results obtained by respondents. Based on the respondents' answers, an isomorphic analysis technique was also conducted. The results of the isomorphic analysis were used to categorize the students' level of concept mastery on Newton's Law. The results of the percentage of students' conceptual understanding level on Newton's Law are described in Table 3.

Table 3. Percentage of Students' Conceptual Understanding Level on Newton's Laws

Understanding (%)	**Moderately Understanding (%)**	**Not Understanding (%)**
2.06%	9.93%	88.01%

The categorization of the level of conceptual understanding is based on the consistency of students' answers when answering three questions in one theme. Table 3 shows that the percentage of students who understanding the concept of Newton's Law is very low when compared to not understanding the concept. In detail, the level of concept mastery in each theme is described in Table 4.

Table 4. Percentage of Students' Conceptual Understanding Level on Newton's Laws

Theme	**Conceptual Understanding Level**		
	Understanding Concept	**Moderately Understanding**	**Not Understanding**
Theme 1	2.54%	16.95%	80.51%
Theme 2	7.63%	21.19%	71.19%
Theme 3	0.85%	3.39%	95.76%
Theme 4	0.00%	12.71%	87.29%
Theme 5	1.69%	0.85%	97.46%
Theme 6	0.00%	9.32%	90.68%
Theme 7	1.69%	5.08%	93.22%

Table 4 shows that the average percentage of students who understanding the concept of Newton's Law is very low when compared to the percentage of students who do not understanding the concept. This is assessed based on the consistency of student answers, so students who do not consistently answer all three questions in one theme correctly are considered not mastering the concept. The percentage of students with the category "not understanding the concept" is highest in Theme 3 with the indicator of analyzing the magnitude of the action-reaction force on two objects that touch each other. One example of a Theme 3 question item is described below.

Theme 3

A big truck collided with a small car. Exactly when the two collided:
a. The truck exerts more force on the car than the car exerts on the truck (66.10%)
b. The car exerts more force on the truck than the truck exerts on the car (6.78%)
c. The car exerts no force on the truck and the car will be destroyed by blocking the truck (2.54%)
d. The truck exerts force on the car but the car does not exert force on the truck (1.69%)
e. The truck exerts a force on the car that is equal to the force the car exerts on the truck* (22.88%)

In this problem, students are expected to apply the concept of Newton's Third Law to determine the magnitude of the action-reaction force acting on the two objects when they collide. Based on the percentage distribution of student answers, it indicates that the majority of students believe that the object with greater mass will exert greater force. Students' failure to answer questions related to the magnitude of the action-reaction force in Theme 3 is in line with the low percentage of students who did not master the concept of Theme 4 with the indicator of determining the appropriate action-reaction force pair. In Theme 4 none of the respondents consistently answered correctly on all three questions. One of the items in Theme 4 is described below.

Theme 4

A beam is suspended under the roof of a house using a rope. In the system, T_1 is the force exerted by the roof on the rope, T_2 is the force exerted by the rope on the roof, F is the force exerted by the beam on the rope, and w is the weight of the beam. Among these forces, the one that shows the action-reaction force pair is ....
a. T_1 with T_2* (5.09%)
b. w with T_1 (26.15%)
c. w with F (31.03%)
d. T_2 with F (37.73%)

In this problem, students are expected to use the concept of Newton's Third Law to determine the action-reaction force pairs correctly, but it appears that the dominant students have inappropriate thinking. Students think that action-reaction force pairs are all forces that are equal in magnitude, opposite in direction and acting on different objects.

Discussion

Overall, students' difficulties were found in all indicators of Newton's Law isomorphic items, and the most dominant difficulty that students have is the difficulty in Newton's Third Law. This is evidenced by the high percentage of students who are inconsistent in answering three parallel questions in one theme. The results of Kusairi et al. (2022) also showed similar results, namely the average value of concept mastery was very low with a score of 7.2 out of 100, but on the respondents of second-year physics education and

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naturanl science education students. The difference in the results of the two studies is in the percentage of students who are “not understanding” and “moderately understanding”. The results of this study showed that the average percentage of students with the categories “moderately understanding” and “not understanding” was 9.93% and 88.01%, respectively, while in Kusairi et al. (2022) was 70.7% and 21.65%, respectively. In addition, study by Serhane et al. (2023) also found a similar thing, that students often fail to apply the concept of Newton's Law in everyday problems, especially in the concept of Newton's Third Law. The difference between this research and the research of Serhane et al. (2023) is in the research instruments used. In this study using a questionnaire and analyzing questions in the form of qualitative analysis.

The low conceptual understanding in Newton's Third Law is due to the lack of students' comprehensive understanding. There are four characteristics of action-reaction force pairs, 1) action-reaction forces occur due to the interaction of two objects, 2) action-reaction forces are equal, 3) action-reaction forces have opposite directions, and 4) action-reaction forces occur on two different objects. Based on the survey results, it shows that students only understand Newton's Law III using only a few characteristics in identifying action-reaction forces. This is evidenced by the findings in Table 3 which shows that students also found difficulties in Theme 4, namely errors in identifying action-reaction force pairs. Based on the percentage of students' answers, students predominantly identify action-reaction force pairs with the characteristics of having the same magnitude, opposite direction, and acting on the same two objects, without understanding that the action-reaction force pair occurs due to the interaction of two objects. This result is in line with the findings in the study of Kusairi et al. (2022), which showed that many students still mistakenly understand that action-reaction forces always work on two different objects. This is possible because students misinterpreted that “action-reaction forces act on two different objects” instead of understanding it as “two interacting objects” (Bao & Fritchman, 2021).

Table 3 also shows that the most dominant difficulty students have in Theme 3 is regarding the magnitude of the action-reaction force pair. Based on students' answers, a total of 66.10% of students think that objects that have a large mass will exert a greater force when interacting. This finding is also in line with the findings of Bouzid et al. (2022), Husin et al. (2019), and Kusairi et al. (2022) where the lowest score on Newton's Law was also found on the concept of action-reaction forces at the college level. This is due to the students’ misconception that when there are two objects with different masses interacting with each other, the object with a large mass will exert a greater force (Wells et al., 2020). Reinforced by the findings of Bouzid et al. (2022), and Serhane et al. (2023), that this thinking arises because students view action-reaction as a “fight” the object with a large mass will be stronger and more dominant in the interaction, besides that students also interpret “reaction” as a result or something that comes after the “action”.

Furthermore, there was also a low conceptual understanding in Theme 4, namely errors in identifying action-reaction force pairs. This result is in line with the findings in the study of Kusairi et al. (2022), which showed that many students still mistakenly understand that action-reaction forces always work on two different objects. This is possible because students misinterpreted that "action-reaction forces act on two different objects" instead of understanding it as "two interacting objects" (Bao & Fritchman, 2021).

The finding of students' difficulties in Newton's Law needs to be a concern in physics learning. The findings in this study indicate that the difficulties are related to misconceptions that were not successfully corrected during the learning process (Afni et al., 2024; Putri et al., 2024). For this reason, it is recommended that teachers conduct an initial diagnosis to detect students' misconceptions and provide appropriate learning methods to help correct students' misconceptions, especially misconceptions in Newton's Third Law.

CONCLUSION

The survey results show that students' mastery of concepts in Newton's Law is low, as evidenced by the findings of student difficulties in the concepts of Newton's Law. The most dominant difficulty is determining the magnitude of the action-reaction force. For this reason, it is recommended that teachers conduct an initial diagnosis to detect students' misconceptions and provide appropriate learning methods to help correct students' misconceptions, especially misconceptions in Newton's Third Law. However, this study has some limitations that need to be considered. This study has research limitations in that it only includes a sample of students from two schools, so generalization of the results to a wider population needs to be done with caution. In addition, the data collection method used was survey-based, which may not fully capture the complexity of students' understanding of Newton's Laws. Further research could consider adding data through in-depth interviews or more comprehensive diagnostic tests, to explore students' understanding in more depth. Further research could also be conducted on appropriate learning methods to help overcome students' difficulties with Newton's Law.

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