Kasuari: Physics Education Journal 8(1) (2025) 1-13
P-ISSN: 2615-2681
E-ISSN: 2615-2673

Kasuari: Physics Education Journal (KPEJ)
Universitas Papua
website: https://journalfkipunipa.org/index.php/kpej

Exploration of High School Students' Difficulties on Newton's Law Material with Isomorphic Tests

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Abstract: *The research aims to analyze students' conceptual understanding of Newton's Law material by utilizing isomorphic tests. This quantitative descriptive research involved 30 male and 40 female respondents from class X MIPA of a private high school in Malang. Data was collected by survey method using a test consisting of 6 description questions adapted from the FCI instrument. The test, which consists of two groups of isomorphic items, has an inter-rater Cohen's kappa test reliability of 0.730 with a standard error of 0.059. Data analysis was carried out in a quantitative descriptive manner. Research found that students' understanding of concepts is very low. The highest score is given to students who understand the concept quite well. The category is based on isomorphic grouping. Students have difficulty in the implementation of Newton's Law II and Newton's Law III. Students' concept understanding is in the category of moderately understanding the concept. The difficulty experienced by students in the first indicator is that they cannot distinguish between the acceleration and speed of an object and assume that mass can affect the acceleration. In the second indicator, students explained that mass affects the interaction of forces.*

Keywords: *concept understanding, FCI, isomorphic test, Newton's law, senior high school*

Eksplorasi Kesulitan Siswa SMA pada Materi Hukum Newton dengan Tes Isomorfik

Abstrak: Penelitian bertujuan menganalisis pemahaman konsep siswa pada materi Hukum Newton dengan memanfaatkan tes isomorfik. Penelitian deskriptif kuantitatif ini melibatkan responden berjumlah 30 laki-laki dan 40 perempuan yang berasal dari kelas X MIPA SMA swasta di Malang. Pengumpulan data dilakukan dengan metode survei menggunakan sebuah tes yang terdiri dari 6 soal uraian diadaptasi dari instrumen FCI. Tes yang terdiri dari dua kelompok butir isomorfik ini memiliki reliabilitas inter raters cohen's kappa tes sebesar 0,730 dengan standar error 0,059. Analisis data dilakukan dengan deskriptif kuantitatif. Penelitian menemukan bahwa pemahaman konsep siswa terbilang sangat rendah. Skor tertinggi dimilki siswa yang berada pada kategori cukup memahami konsep. Kategori tersebut berdasarkan pengelompokan siomorfis. Siswa mengalami kesulitan pada implementasi Hukum II Newton dan Hukum III Newton. pemahaman konsep siswa berada pada kategori cukup memahami konsep. Kesulitan yang dialami siswa pada indikator pertama adalah tidak bisa membedakan percepatan dan kecepatan suatu benda dan beranggapan bahwa massa dapat mempengaruhi perecpatan. Pada indikator kedua, siswa menjelaskan bahwa massa mempengaruhi interaksi gaya.

Kata kunci: FCI, hukum Newton, pemahaman konsep, SMA, tes isomorfik

INTRODUCTION

Newton's laws are important material for students to understand because they are one of the fundamental laws in physics. However, some students still have difficulty applying the basic concepts of Newton's law (Fadlli et al., 2019; Parno et al., 2021; Taqwa et al., 2020). A common difficulty for students when working on physics is formulating mathematical formulas related to Newton's laws, for example, calculating forces and understanding the relationship between mass, acceleration, and force (Erfan & Ratu, 2018; Isra & Mufit, 2023; Rusilowati et al., 2021; Saregar et al., 2020; Setyani et al., 2017). Moreover, students often memorize equations without understanding the meaning of the memorized equations more deeply (Januarifin et al., 2018). The habit of students memorizing mathematical equations without understanding the conceptual meaning is the result of conventional learning methods that are still applied by some educators (Alias & Ibrahim, 2017; Low et al., 2023; Lutz et al., 2017). Research conducted by Serhane et al. (2020) and Mansyur et al. (2020) explains that students experience failure in understanding the context of Newton's Law III, where students misunderstand the reciprocal nature of action-reaction forces. In addition, students also have difficulty applying Newton's legal concepts to real situations because students have a different initial understanding (naïve) of the scientific concepts of Newton's law (Burkholder, 2024; Erfan & Ratu, 2018; Fadaei & Mora, 2015; Lutz et al., 2017; Serhane et al., 2020; Sudiarta, 2020).

Research on the identification of students' difficulties in Newton's Law material has been carried out by many other researchers (Als Mustofa et al., 2024; Cashata et al., 2022; Farihah & Wildani, 2018; Serhane et al., 2020; Sitepu & Yakob, 2019). One of the efforts that can be used to find out students' difficulties as early as possible is to use diagnostic tests (Bawamenewi et al., 2024; Juita et al., 2023; Permana et al., 2022; Putri et al., 2024; Subali et al., 2022) and instruments that have been developed by previous researchers (Cashata et al., 2022; Hestenes et al., 1992; Hestenes & Wells, 1992; Nadhiif et al., 2015; Thornton & Sokoloff, 1998). On the other hand, the use of *multiple tiers* in diagnostic tests of concept understanding has been criticized by some researchers. Using *a six-tier diagnostic test* involving several steps in one question requires a lot of time, so it is considered inefficient. Alternatively, researchers began to use isomorphic tests to examine students' understanding of concepts including physics concepts, such as Newton's Law.

Isomorphic test instruments have long been developed and studied by previous researchers, both on isomorphic with two question items (Bassok & Holyoak, 1989; Lin & Singh, 2011; Madhyastha & Hunt, 2009) and isomorphic with three question items (Alatas et al., 2021; Ding & Beichner, 2009; Nguyen & Rebello, 2011; Nieminen et al., 2010; Suganda et al., 2020). Both isomorphic types can be used to identify student misconceptions. However, the most effective isomorphic method used to detect misconceptions is to use 3 question items (Nadhiif et al., 2015). Research conducted in Indonesia to identify students' conceptual understanding of Newton's law material using isomorphic problems can be quite rare, most researchers use *multiple-tier* instruments. This is based on the results of a review on the *Google Scholar page*.

The research conducted by Alatas et al. (2021) discusses the success of identifying misconceptions among junior high school students with 90 respondents on the topic of Newton's law using isomorphic test instruments. The results of this study show that misconceptions experienced by students and the use of isomorphic tests can easily produce accurate data about dominant and recessive students. In line with that, a study on the correlation between the use of isomorphic, *open-ended*, and conventional instruments conducted by Suganda et al. (2020) concluded that isomorphic instruments are more beneficial than the other two instruments.

Based on the description that has been described, this study uses an isomorphic test instrument to identify students' difficulties. This study chose to use isomorphic instruments because, in previous research, isomorphic tests were only used to investigate the misconceptions of junior high school students on Newton's Law material. However, this isomorphic test has not been widely used in the assessment of Newton's Law or physics at the high school level. The most important aspect of this study is to identify students' understanding of concepts quickly and appropriately using instruments that can explore students' understanding of concepts. In addition to the use of isomorphic instruments which are rarely used in physics assessments, this research also offers new colors in isomorphic instruments. Isomorphic instruments that generally use multiple-choice tests are modified into descriptive tests. This up-to-date makes isomorphic researchers more consistent in identifying the problems experienced by students because they are equipped with additional explanations from students that vary. Therefore, the purpose of this study is to use isomorphic tests to explore students' difficulties in understanding the concept of Newton's Law. The isomorphic test used is a modification of the previous instrument, namely *the Force Concept Inventory* (FCI).

METHOD

The descriptive quantitative method in this study uses a survey model as a data collection technique, where the survey data is in the form of quantitative data. The subjects of this research are 70 students of class X MIPA from private high schools in the city of Malang who have studied Newton's Law. The selection of students was carried out randomly, where the specific number of respondents was 30 male students and 40 female students.

The research instrument contains 6 questions that require students to provide true or false conclusions from the statements presented accompanied by reasons. This instrument was adapted from the FCI multiple-choice questions (Hestenes et al., 1992), and modified into essay questions with isomorphic type. Isomorphic questions consist of the same concept but the redactions are different and randomly placed. The researcher chose essay questions to minimize cheating that may occur when students are doing the questions. In addition, essay questions produce diverse student answer data. Modifications to the FCI questions are also made by changing the language so that it is easy for students to understand and avoid the occurrence of double meanings in interpreting. The modification was carried out with the help of experts from the Department of Physics, State University of Malang. There are two indicators of questions used in the research instrument, namely 1) students can apply Newton's Law II to the motion of objects; and 2) students can apply the concept of Newton's Law III in every situation. In order, the first indicator is located at numbers 1, 3, and 6 and the second indicator is located at numbers 2, 4, and 5.

Question instruments are validated by experts, so they are suitable for use as a measuring tool. In addition, the researcher also conducted an inter-rater reliability test conducted by two assessors to determine the perception of assessment between assessors on the results of student answers. The reliability test showed a value of 0.730, which means that the perception of student answer analysis by the two assessors was in the substantial category (Kimambo et al., 2021; Mourtzikou et al., 2022; Naqvi et al., 2020). Furthermore, the researcher collected data by providing the questions to the respondents through the subject teacher. Students as respondents worked on questions in the form of essays individually within 45 minutes in class. During the test, the supervisor ensured that no students collaborated in solving the questions. The results of the answers that have been collected are then assessed following the scoring guidelines. The maximum score that students can

get for each question is 3. Then, the total score is converted to the final score with the formula, Equation 1.

$$NA = \frac{n}{18} \times 100 \quad (1)$$

Information:
NA : Final score
n : Total

The researcher also categorizes students' understanding of concepts as isomorphic by assuming that if students can correctly answer all three questions with the same indicators, then students are said to understand concepts (MK). However, if students can only answer two correct questions, then they are categorized as understanding the concept (CK). If one question is correct or the third question is wrong, then students are considered not to understand the concept (TK) (Suganda et al., 2020). The results of student answers that have been processed following the scoring and categorization guidelines are analyzed with descriptive statistics. Where the results of the analysis explain the mean, standard deviation, highest score, and lowest score.

RESULTS AND DISCUSSION

Results

The results of the descriptive analysis stated that the average isomorphic score of the students' answers was 16.40. The average is in the very low category (Sudianto et al., 2024). The maximum score obtained by one of the students is 67. The value is in the medium category (Mahfudhah et al., 2022).

Table 1. Descriptive Statistics of Student Answer Results

	N	Minimum	Maximum	Mean	Std. Deviation
Identification Results	70	6	67	16.40	11.159
Valid N (listwise)	70				

The average score of the student answers to each question in detail can be seen in Table 2. The lowest average is in question 1 with an average of 0.04 and a standard deviation of 0.359. The highest average in question 3 reached > 0.9 with a standard deviation of > 0.3.

Table 2. Descriptive Statistics for each Question Item

	N	Min	Max	Mean	Std. Deviation
Question 1	70	0	3	.04	.359
Question 2	70	0	3	.50	.608
Question 3	70	0	3	.94	.376
Question 4	70	0	3	.23	.618
Question 5	70	0	3	.90	1.264
Question 6	70	0	3	.31	.910
Valid N (listwise)	70				

An interesting finding in this study is that in each question there is at least one student who successfully answers using the correct concept and gets 3 points (see Table 3). In addition, there are also quite a lot of students who get 1 point and are almost spread across every question. Even in question number 3, the majority of students got point 1. In this case, point 1 obtained by the majority of students in question number 3 shows that students can conclude that the statement is true or false.

Table 3. Percentage of Students' Concept Understanding Category for each Question Item

Sub Material	Question Number	Calculation of Student Points for Each Question				Percentage of Concept Understanding Category		
		0	1	2	3	MK	CK	TK
Newton's Law II	1	69	0	0	1	0%	1%	99%
	3	6	63	0	1			
	6	62	1	0	7			
Newton's Law III	2	39	29	1	1	0%	1%	99%
	4	60	5	4	1			
	5	42	10	1	17			

Based on isomorphic assessments, no student answered correctly on all three questions with the same indicators. However, the highest score obtained by students in each indicator is 6 points with a score of 3 on two questions. The score shows that the level of understanding of students is in the category of quite understanding concepts (CK), Table 3.

The exploration of the difficulties experienced by students when solving the problem is explained in the sample answers from two questions with each indicator. Question 1 represents the first indicator with the majority of students' answers getting 0 points and is the question with the highest number of 0s in indicator 1, Table 3. Question 1 contains a statement about two spheres that have different masses and are dropped at the same height, then the object with the greater mass will reach the ground first. Students are asked to determine whether the statement is true or false and provide supporting reasons to explain the phenomenon. The results of the students' answers are listed in Figure 2 and Figure 3.

1. Dua bola A dan B memiliki massa 2 kg dan 1 kgmemiliki diameter sama dijatuhkan dari ketinggian yang sama, maka bola A akan jatuh terlebih dahulu karena massanya lebih besar.

Figure 1. Question Number 1

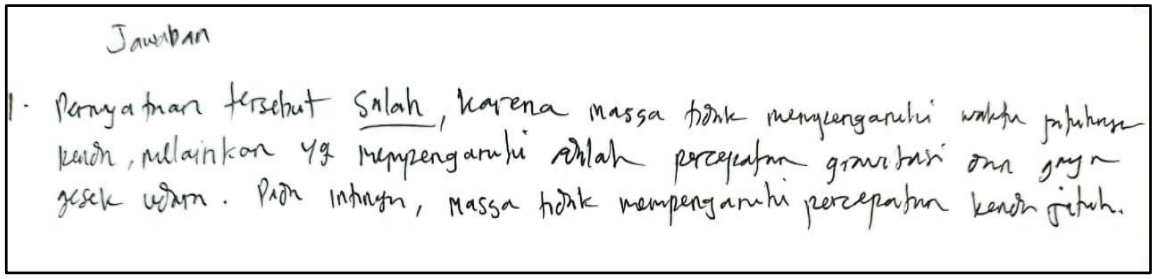

Figure 2. Correct Answer to Question Number 1

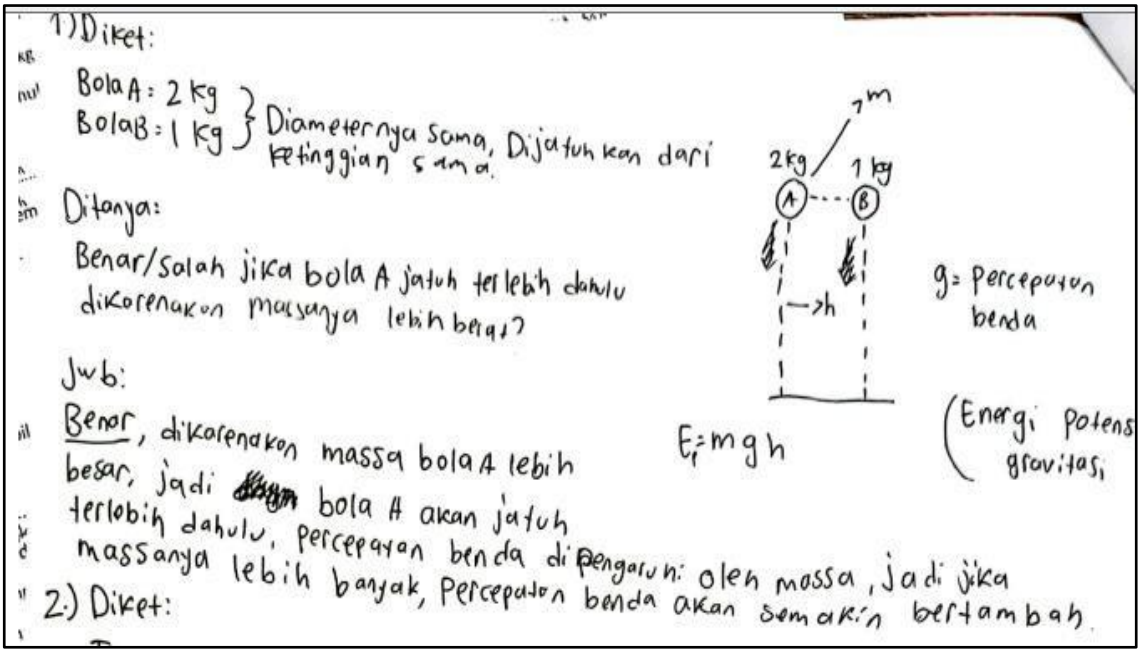

Figure 3. Wrong Answer to Question Number 1

Based on Figure 2, students get 3 points, because they can successfully conclude whether the event is true or false and can provide an explanation based on the concept. of the event and were able to explain the concept. Meanwhile, in Figure 3, students get 0 points for giving the wrong conclusion and the right reason.

Based on Table 3, question 4 has the most 0 points in the second indicator owned by 60 children. Question 4 produces more varied answers can be seen in Figure 5, Figure 6, and Figure 7. The question contains a statement about a motorcycle hitting a car driving from the opposite direction. In this event, the force given by the car is greater, so the motorcycle bounces. Students are asked to give conclusions from the statement as true/false and provide explanations that are by the concept of Newton's Law III based on the events that occurred.

4. Motor yang dikendarai Ari kehilangan kendali, sehingga menabrak mobil Avanza yang melaju dari arah berlawanan yang mengakibatkan motor Ari terpental sejauh 5 meter, namun mobil tetap berada di lokasi kejadian. Tepat pada saat tabrakan, gaya yang diberikan oleh mobil ke sepeda motor lebih besar daripada gaya yang diberikan motor ke mobil, sehingga hal tersebut menyebabkan motor terpental.

Figure 4. Question Number 4

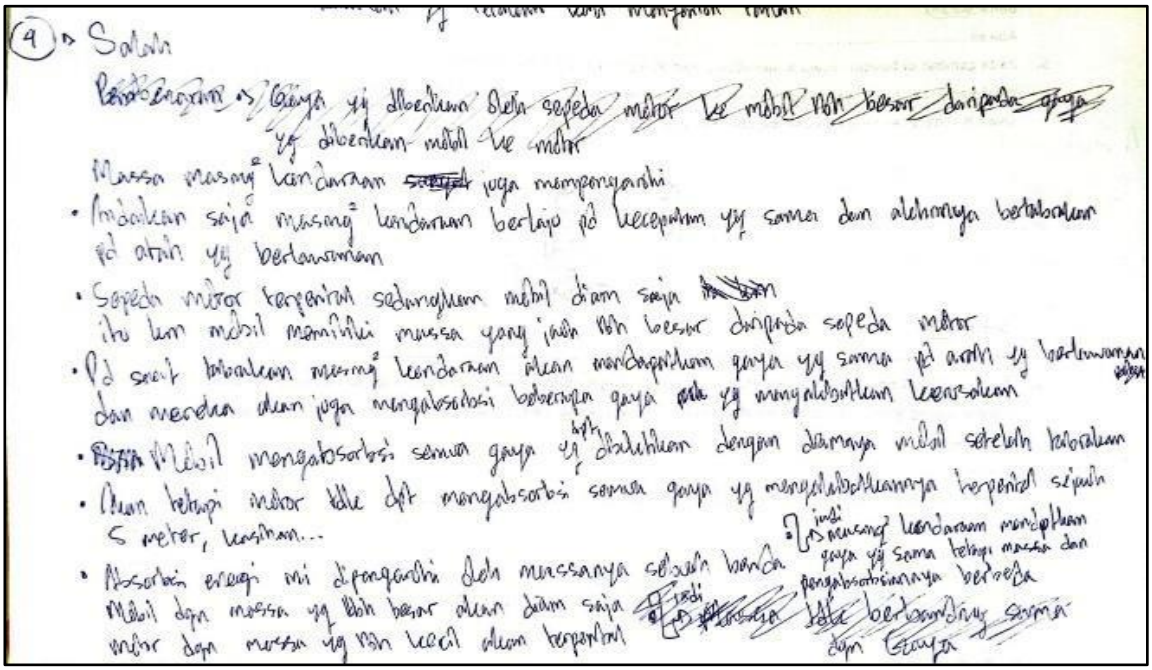

Figure 5. Correct Answer to Question Number 4

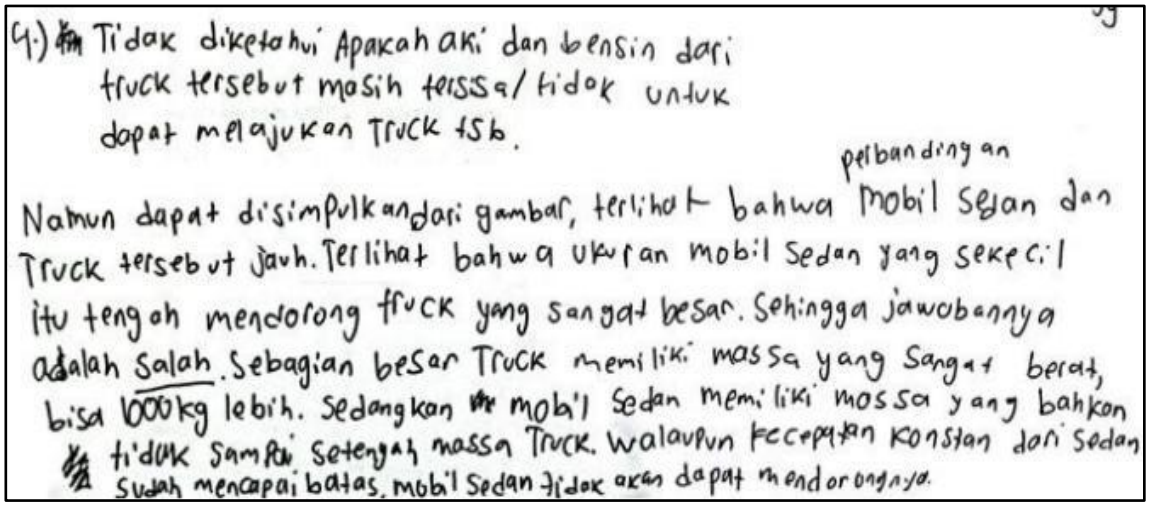

Figure 6. Wrong Answer to Question Number 4

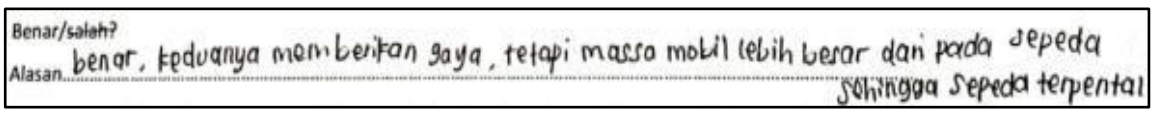

Figure 7. Wrong Answer to Question Number 4

In Figure 4, students get maximum points because they managed to conclude the event and provide the correct explanation. In Figure 5, students get 2 points because it is wrong to give a conclusion, but the explanation given follows the concept. Meanwhile, in Figure 6, the student gets 1 point because they only succeeded in concluding the right or wrong of the event, but failed in providing an explanation in accordance with Newton's Law III theory.

Discussion

Based on the data that has been described, it is known that none of the students can be categorized as understanding the concept when answering the 6 questions. The maximum score obtained by students on the two indicators is 6 points. Students who successfully answer two correct questions with the same indicator can be categorized as understanding the concept based on isomorphic assessment. The CK category is only owned by two students. Student 1 is in the CK category in the question with the first indicator, while student 2 is also in the CK category in the question with the second indicator. Students are unable to answer all three questions with the same indicators due to several difficulties experienced. In addition, students who get 1 point are also almost spread across every question. The failure experienced by students is that they are unable and do not understand the ideas given to each question, so they fail to conclude to answer each question with the same indicators. In addition, they failed to explain the reason for the cause and the majority of students answered not according to the concept, even using their naïve theories. The results of research conducted by Alatas et al. (2021) also suggested that isomorphic tests accurately detect the difficulties of students who experience misconceptions in Newton's Law material.

The majority of students' difficulties identified in question 1 are errors that occur because students cannot distinguish acceleration and velocity. Students claim speed is directly proportional to mass, but the formula used is Newton's Second Law $\vec{F} = m.\vec{a}$. In the formula of Newton's Second Law, it is very clear that the sign $\vec{a}$ is *acceleration* which means acceleration not speed. In Figure 3, student 2 answered question 1 with the concept of potential energy, namely objects that have the same height, but different masses, $E_p = m.g.h$. The objects with the heavier mass will arrive first. Students assume that the greater the mass of an object, the greater the acceleration. The majority of student answers assume that mass affects the acceleration of an object. Students still have difficulty in determining the relationship between mass and acceleration. Students do not understand that the event is related to Newton's Law II regarding the acceleration of an object which is directly proportional to the resultant force acting on it, and inversely proportional to its mass (Serway & Jewett, 2014)

This is because students tend not to pay attention to implied things such as the influence of gravitational acceleration and air friction. Most students use the potential energy formula based on the data or information provided in the questions and their naïve theories through daily observations. Students do not realize that if the height of an object increases, it will cause an increase in the potential energy of an object and its kinetic energy decreases. Research conducted by Alatas et al. (2021) also explained that students tend to assume that the acceleration of an object is directly proportional to the mass of the object. Difficulties in understanding this concept are also experienced by students who are more familiar with using formulas and tend to use rote techniques, as a result their concept understanding of Newton's Law II is low (Sulman et al., 2022)

In the question with the second indicator, the majority of students' answers were that objects with a larger mass will exert a greater force on objects with a smaller mass. Students' answers and reasons varied in question 4. Based on the students' answers in Figures 5 and 6, they explained that mass also affects the force exerted and received by an object. In addition, the student's answer in Figure 5 gives an incorrect answer, but he understands that the two objects exert the same magnitude of force on each other, but there is no further explanation regarding the amount of force received by the two objects and claims that what causes the lighter object to bounce is due to the difference in mass. The concept that should be understood by students is when object I exerts a force on object II

(action force), while object II exerts the same force on the first object in the opposite direction (reaction force) (Giancoli, 2005).

Students' difficulties in understanding the application of Newton's Law III in various circumstances stem from the naïve theory. Students assume that the force exerted by two interacting objects is not always equal in magnitude, but depends on other external factors, such as mass, velocity, and the state of motion of the object. This is also revealed in a study that has been conducted by Savinainen (2017) which also explains the same thing. Other students' perceptions are also similar to the explanation of Bao et al. (2002 dan Sujarittham (2019) stated that two interacting objects have different masses, the more massive object must exert more force than the smaller one. Other research explains that when one object pushes another object, the pushing object must exert a greater force than the pushed object (Mansyur et al., 2020).

Students ignore that two interacting objects exert force on each other with the same value but in different directions (Serway & Jewett, 2014). In this case, students also misinterpret that $\vec{F} = -\vec{F}$ has a different value because they are deceived by a negative sign that is supposed to indicate direction, but they assume that the negative sign indicates the magnitude of the force. The students' answers also explained that the reason why the motorbike can bounce is due to the difference in the mass of the two, they do not pay attention to the acceleration that applies to both, referring to Newton's theory of Law II with the formula $\vec{F} = m.\vec{a}$. The motorbike can bounce and the car remains stationary because the two objects have the same magnitude of force with different masses, so the motorbike will experience greater acceleration in the opposite direction to the initial direction of the motorbike. The acceleration owned by the car is much smaller than the acceleration of a motorcycle.

Questions with isomorphic types consistently provide valid information about students' understanding of the concepts contained in the questions. This is a solution to make it easier and quickly identify the difficulties experienced by students so that they can be minimized. This is because the sooner it is identified, the faster and more appropriate the learning treatment that can be given. Research by Suganda et al. (2020) explains that isomorphic tests are more effective in measuring students' learning difficulties. Teachers can use 3 isomorphic questions, both before and after starting learning to check students' understanding of concepts. Using 3 isomorphic questions with a description question format will be more detailed in revealing students' concepts understanding. This is because the answers that emerge from students' thoughts are interesting and the reasons expressed are sometimes unpredictable. This is also the difference between this study and the previous study, but, using the type of description questions will take longer and more thorough to assess. If you want a shorter time, you can use 3 multiple-choice isomorphic questions. However, using this type of question cannot further reveal the student's understanding, unless an interview is conducted or a reasoned multiple-choice is used.

The weakness of this study is that the number of student participation is limited to only one school. It is recommended to conduct research with a larger number of participants and come from different schools so that the results obtained are more varied. In addition, the data obtained is more varied, but it can also produce and describe students' ability to understand more valid concepts.

CONCLUSION AND SUGGESTIONS

The isomorphic test used in this study proves its consistency in identifying students' understanding of concepts so that the difference between students who experience

difficulties and those who already understand concepts can be known. Students experience difficulties in both indicators, namely Newton's Law II and Newton's Law III. This study showed that the majority of students did not understand the concept and only 2 students were in the category of understanding the concept sufficiently.

The mistakes that are described by many students in each indicator in order are as follows: 1) considering mass as the main factor for the object to reach the bottom first when it is dropped from the same height; 2) linking the relationship of mass and altitude according to the potential energy formula; 3) mass affects objects when interacting; 4) the state of the object affects the interaction of both; and other factors.

This study implies that the condition of students with difficulty understanding Newton's Law material can be used as a reference in compiling physics learning. In addition, further research can be carried out using isomorphic problems on different materials and with different innovations. This is because isomorphic tests are proven to be able to explore the difficulties experienced by students by providing consistent results, so isomorphic tests are feasible as an option for researchers and teachers to be used as assessment test instruments.

REFERENCES

Alatas, F., Ilhamiah, S., & Suryadi, A. (2021). Identification of Students' Misconceptions Using Isomorphic Test: the Case of Newton's Law of Motion. *Edusains*, *13*(2), 174–184. https://doi.org/10.15408/es.v13i2.23967

Alias, S. N., & Ibrahim, F. (2017). The Effectiveness of Educational Games on Newton's Laws Learning. *Journal of Nusantara Studies (JONUS)*, *2*(1), 71. https://doi.org/10.24200/jonus.vol2iss1pp71-85

Als Mustofa, H., Sandanadas, E., Mohtar, L. E., & Faresta, R. A. (2024). Identifying Student Prior-Knowledge and Conceptual Changes Profile on Newton Law Using by using POE (Predict, Observe, and Explain) as Probing Understanding Strategy. *Journal of Science and Mathematics Letters*, *12*(1), 80–91. https://doi.org/10.37134/jsml.vol12.1.10.2024

Bao, L., Hogg, K., & Zollman, D. (2002). Model Analysis of Fine Structures of Student Models: An Example with Newton's Third Law. *American Journal of Physics*, *70*(7), 766–778. https://doi.org/10.1119/1.1484152

Bassok, M., & Holyoak, K. J. (1989). Interdomain Transfer Between Isomorphic Topics in Algebra and Physics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(1), 153–166. https://doi.org/10.1037/0278-7393.15.1.153

Bawamenewi, A., Sari, S. Y., Mufid, F., & Dewi, W. S. (2024). *Analysis of Misconceptions of Class X High School Students in Padang City About Newton's Law Material Using Four-Tier Multiple Choice Diagnostic Test*. *2*(2), 89–96.

Burkholder, E. (2024). *A Momentum-First Approach to Newton's Second Law*. *11*, 1–5.

Cashata, Z. A., Seyoum, D. G., & Alemu, S. A. (2022). Assessing Students' Factual, Conceptual, and Procedural Knowledge of Newton's Laws of Motion. *Momentum: Physics Education Journal*, *6*(2), 199–213. https://doi.org/10.21067/mpej.v6i2.6664

Ding, L., & Beichner, R. (2009). Approaches to Data Analysis of Multiple-Choice Questions. *Physical Review Special Topics - Physics Education Research*, *5*(2), 1–17. https://doi.org/10.1103/PhysRevSTPER.5.020103

Erfan, M., & Ratu, T. (2018). Analysis of Students' Difficulties in Understanding the Concept of Newton's Law of Motion. *Jurnal Ilmu Pendidikan Fisika*, *3*(1), 1–4.

Fadaei, A. S., & Mora, C. (2015). An Investigation About Misconceptions in Force and Motion in High School. *US-China Education Review A*, *5*(1), 38–45.

https://doi.org/10.17265/2161-623x/2015.01.004

Fadlli, M. R., Sutopo, S., & Wartono, W. (2019). Analisis Kesulitan Siswa dalam Menyelesaikan Soal Hukum Newton. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *4*(8), 993. https://doi.org/10.17977/jptpp.v4i8.12652

Farihah, U., & Wildani, A. (2018). Identifikasi Miskonsepsi Siswa dengan Three Tier Essay Test Item Pada Materi Hukum Newton di SMA Negeri 1 Pademawu. *Wacana Didaktika*, *6*(01), 86–100. https://doi.org/10.31102/wacanadidaktika.6.01.86-100

Giancoli, D. C. (2005). *Physics: Principles with Application* (6th ed). Pearson Prentice Hall.

Hestenes, D., & Wells, M. (1992). A Mechanics Baseline Test. *The Physics Teacher*, *30*(3), 159–166. https://doi.org/10.1119/1.2343498

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158. https://doi.org/10.1119/1.2343497

Isra, R. A., & Mufit, F. (2023). Students' Conceptual Understanding and Causes of Misconceptions on Newton's Law. *International Journal of Evaluation and Research in Education*, *12*(4), 1914–1924. https://doi.org/10.11591/ijere.v12i4.25568

Januarifin, D., Parno, P., & Hidayat, A. (2018). Kesalahan siswa SMA dalam memecahkan masalah pada materi Hukum Newton. *Momentum: Physics Education Journal*, *2*(2), 47–55. https://doi.org/10.21067/mpej.v1i1.2292

Juita, Z., Sundari, P. D., Sari, S. Y., & Rahim, F. R. (2023). Identification of Physics Misconceptions Using Five-tier Diagnostic Test: Newton's Law of Gravitation Context. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 5954–5963. https://doi.org/10.29303/jppipa.v9i8.3147

Kimambo, D., Kennedy, S., Kifai, E., Kailembo, N., Eichberg, C., Markosky, S., Shah, I., Powers, E., Zwerner, P., Dorman, S. E., Janabi, M., & Bayer, R. (2021). Feasibility of Point-of-Care Cardiac Ultrasound Performed by Clinicians at Health Centers in Tanzania. *BMC Cardiovascular Disorders*, *21*(1), 1–9. https://doi.org/10.1186/s12872-021-02045-y

Lin, S. Y., & Singh, C. (2011). Using Isomorphic Problems to Learn Introductory Physics. *Physical Review Special Topics - Physics Education Research*, *7*(2), 1–16. https://doi.org/10.1103/PhysRevSTPER.7.020104

Low, J. Y., Balakrishnan, B., & Yaacob, M. I. H. (2023). Educational Game-based Design Training on Newton's Laws for Physics Teachers: A Need Analysis for Module Development. *Asian Journal of Education and Social Studies*, *45*(4), 9–19. https://doi.org/10.9734/ajess/2023/v45i4988

Lutz, J., Sylvester, K., Oliver, K., & Herrington, D. (2017). 3, 2, 1 … Discovering Newton's Laws. *The Physics Teacher*, *55*(3), 149–151. https://doi.org/10.1119/1.4976656

Madhyastha, T., & Hunt, E. (2009). Mining Diagnostic Assessment Data for Concept Similarity. *JEDM - Journal of Educational Data Mining*, *1*(1), 72–91. http://www.educationaldatamining.org/JEDM/index.php/JEDM/article/view/10

Mahfudhah, A., Hamidah, D., & Wulan, E. R. (2022). Lectora Inspire Interactive E-Module with a Realistic Approach to Facilitate Understanding of Mathematical Concepts. *Al-Khwarizmi: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam*, *10*(1), 35–60.

Mansyur, J., Kaharu, S. N., & Holdsworth, J. (2020). A Simple Approach to Teach Newton's Third Law. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 79–90.

https://doi.org/10.15294/jpii.v9i1.21775

Mourtzikou, A., Tsiftsis, D., Agrogianni, M., Kasimatis, N., Dritsa, A., Stamouli, M., Koumpouros, P., Seitopoulou, C., & Toka, E. (2022). A Synchronous Blind Test and Methodological Comparison Between Colloidal Gold Rapid Test vs RT-PCR For Sars-Cov-2 Detection. *European Journal of Biomedical Research*, *1*(5), 7–12. https://doi.org/10.24018/ejbiomed.2022.1.5.26

Nadhiif, M. A., Diantoro, M., & Sutopo. (2015). Tes Isomorfik Berbasis Komputer untuk Diagnostik Miskonsepsi Diri pada Materi Gaya dan Hukum Newton. *Jurnal Pendidikan Sains*, *3*(2), 58–67.

Naqvi, A., Manglik, N., Dudrey, E., Perry, C., Mulla, Z. D., & Cervantes, J. L. (2020). Evaluating the Performance of a Low-Cost Mobile Phone Attachable Microscope in Cervical Cytology. *BMC Women's Health*, *20*(1), 1–6. https://doi.org/10.1186/s12905-020-00902-0

Nguyen, D. H., & Rebello, N. S. (2011). Students' Understanding and Application of the Area Under the Curve Concept in Physics Problems. *Physical Review Special Topics - Physics Education Research*, *7*(1). https://doi.org/10.1103/PhysRevSTPER.7.010112

Nieminen, P., Savinainen, A., & Viiri, J. (2010). Force Concept Inventory-Based Multiple-Choice Test for Investigating Students' Representational Consistency. *Physical Review Special Topics - Physics Education Research*, *6*(2), 1–12. https://doi.org/10.1103/PhysRevSTPER.6.020109

Parno, P., Mufidah, J., Diantoro, M., & Ali, M. (2021). Building Conceptual Understanding of Students on Laws of Newton Through Argument-Driven Inquiry. *AIP Conference Proceedings*, *2330*(March). https://doi.org/10.1063/5.0043127

Permana, A. H., Sekartaji, A., & Ambarwulan, D. (2022). Development of Diagnostic Test of Learning Difficulties for High School on Newton's Law Material using Moodle Learning Platform. *Journal of Physics: Conference Series*, *2377*(1). https://doi.org/10.1088/1742-6596/2377/1/012070

Putri, V. A., Sundari, P. D., Mufit, F., & Dewi, W. S. (2024). Analysis of Students' Physics Conceptual Understanding using Five-Tier Multiple Choice Questions: the Newton's Law of Motion Context. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2275–2285. https://doi.org/10.29303/jppipa.v10i5.5847

Rusilowati, A., Susanti, R., Sulistyaningsing, T., Asih, T. S. N., Fiona, E., & Aryani, A. (2021). Identify Misconception with Multiple Choice Three Tier Diagnostic Test on Newton Law Material. *Journal of Physics: Conference Series*, *1918*(5), 1–8. https://doi.org/10.1088/1742-6596/1918/5/052058

Saregar, A., Mulyani, H., Yetri, Y., Anugrah, A., & Ravanis, K. (2020). An Analysis of Epistemological Learning Barriers on Newton's Law Material in Engineering Class. *Journal of Innovation in Educational and Cultural Research*, *1*(2), 77–86. https://doi.org/10.46843/jiecr.v1i2.14

Savinainen, A. (2017). The Effect of Using a Visual Representation Tool in a Teaching-Learning Sequence for Teaching Newton's Third Law. *Research in Science Education*, *47*(1), 119–135. https://doi.org/10.1007/s11165-015-9492-8

Serhane, A., Debieche, M., Karima, B., & Zeghdaoui, A. (2020). Overcoming University Students' Alternative Conceptions in Newtonian Mechanics. *American Journal of Networks and Communications*, *9*(2), 22. https://doi.org/10.11648/j.ajnc.20200902.12

Serway, & Jewett. (2014). *Physics for Scientists and Engineers with Modern Physics 9ed*. https://drive.google.com/file/d/0B3tL3esqtqcbLVNWUFBLTnp4bTg/view

Setyani, N. D., Cari, C., Suparmi, S., & Handhika, J. (2017). Student's Concept Ability of Newton's Law Based on Verbal and Visual Test. *International Journal of Science and Applied Science: Conference Series*, *1*(2), 162. https://doi.org/10.20961/ijsascs.v1i2.5144

Sitepu, E. B., & Yakob, M. (2019). Analisis Miskonsepsi Siswa pada Materi Hukum Newton di Kelas X IPA SMA Negeri 1 Berastagi. *GRAVITASI: Jurnal Pendidikan Fisika dan Sains*, *2*(02), 23–29. https://ejurnalunsam.id/index.php/JPFS/article/view/1708

Subali, B., Widayati, N. T., Sekarningtias, F. O., Wiyanto, W., Ellianawati, E., & Siswanto, S. (2022). Development of a Four-Tier Test with a Metacognitive Perspective Approach on the Topic of Newton's Laws. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah*, *7*(1), 25–34. https://doi.org/10.24042/tadris.v7i1.9615

Sudianto, A., Rosyadi, & Yusuf. (2024). Evaluasi Tingkat Pemahaman Konsep Siswa pada Materi Komponen Ekosistem dan Interaksi Antar Komponen Kelas X SMA Negeri 2 Bayan Kabupaten Lombok Utara. *Otus Education: Jurnal Biologi dan Pendidikan Biologi*, *2*(2), 89–102. https://doi.org/10.62588/otusedu.2024.v2i2.0111

Sudiarta, I. W. (2020). Alternative Formulation of Physical Laws of Motion. *Indonesian Physical Review*, *3*(3), 132–137. https://doi.org/10.29303/ipr.v3i3.66

Suganda, T., Kusairi, S., Azizah, N., & Parno, P. (2020). The Correlation of Isomorphic, Open-Ended, and Conventional Score on the Ability to Solve Kinematics Graph Questions. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *6*(2), 173–180. https://doi.org/10.21009/1.06204

Sujarittham, T. (2019). A Case Study of a Teaching and Learning Sequence for Newton's Third Law of Motion Designed by a Pre-Service Teacher. In *Journal of Physics: Conference Series,* 1380 (1), 1-9. https://doi.org/10.1088/1742-6596/1380/1/012102

Sulman, F., Yuliati, L., Kusairi, S., & Hidayat, A. (2022). Hybrid Learning Model: Its Impact on Mastery of Concepts and Self-Regulation in Newton's Second Law Material. *Kasuari: Physics Education Journal (KPEJ)*, *5*(1), 65–74. https://doi.org/10.37891/kpej.v5i1.273

Taqwa, M. R. A., Shodiqin, M. I., & Zainuddin, A. (2020). Kesulitan Mahasiswa dalam Memahami Konsep Gaya dan Gerak. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *10*(1), 25–39. https://doi.org/10.24929/lensa.v10i1.86

Thornton, R. K., & Sokoloff, D. R. (1998). Assessing student learning of Newton's laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula. *American Journal of Physics*, *66*(4), 338–352. https://doi.org/10.1119/1.18863