Students' conceptual understanding and causes of misconceptions on Newton's Law

Rania Atara Isra, Fatni Mufit
Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Padang, Padang, Indonesia

Article Info

Article history:

Received Sep 27, 2022
Revised Sep 1, 2023
Accepted Sep 15, 2023

Keywords:

Causes of misconceptions
Five-tier multiple choice
Misconceptions
Newton's Laws
Understanding concepts

ABSTRACT

The aim of this research is to examine students' conceptual comprehension and misconception causes on Newton's Law material with a survey research method. The data collection instruments used five-tier multiple-choice tests and teacher interview guidelines. The sample selected was 259 students from three schools with the school categories of high, medium, and low as well as three physics teachers in these schools. The research results showed that the average misconception in the high, moderate, and low-category schools was, respectively, 19.4%, 20.61%, and 37.82% with the most misconceptions of each school category, on how to describe the force acting on objects, on how to investigate the direction of motion of objects on a particular trajectory, and on how to explain Newton's Law I and the nature of inertia. Students in low-category schools experienced more misconceptions than medium and high-category school learners. The causes of misconceptions in the three categories of schools mostly came from the personal thoughts of the learners themselves. The implication of this research is that students in all school categories tend to experience misconceptions, mainly due to personal thoughts. Teachers are advised to identify and remediate students' misconceptions so that they do not hinder their learning progress.

Corresponding Author:

Fatni Mufit
Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Padang
Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia
Email: fatni_mufit@fmipa.unp.ac.id

1. INTRODUCTION

Concepts comprehension is important in learning science because one of the aspects of scientific literacy is that students can grasp science concepts. Among the issues in physics learning, students often only memorize physics formulas without understanding the formulas and do not care about understanding physics concepts [1]–[3]. These students are often unable to apply physics learning in everyday life. The habit of students who only memorize physics formulas without caring about the concepts can hinder their learning process [4]. In learning physics, students should know and understand the concepts besides memorizing physics formulas. Learners are said to have concepts if they have a clear understanding and are following the real meaning. Conceptual knowledge is knowledge in the form of comprehension, definition, characteristics, and components of an object.

From the results of some studies, not all of students are able to comprehend the concepts taught during learning correctly. Many of these learners have a different understanding than the average physicist [5]–[8]. This distinct understanding is popularly called misconception. A misconception is the concepts comprehended by students in a way that is different from the concepts proposed by previous researchers [2], [9]–[14]. Misconceptions are also defined as significant differences between a person's understanding of concepts and their actual concepts and meanings [15], [16]. Misconceptions occur in all concepts of physics, such as in the fields of mechanics, optics and waves, heat and thermodynamics, electricity and magnetism, modern physics, and the solar system. Misconceptions in the field of mechanics are more studied than in other fields [2], [4], [16]. Newton's Law belongs to the materials in physics subject that students still experience many problems because of a lack of concepts mastery regarding force, Law of Newton I, Law of Newton II, and Law of Newton III [17].

One of the solutions to the problem of misconceptions is to identify and remediate them. The use of diagnostic tests is one of the alternatives to figure out students' misconceptions [13], [18]. Tests of diagnostic are tests designed for the purpose to precisely figure out and identify the weaknesses and strengths of students in a particular lesson [2], [11], [18], [19]. A diagnostic test is an instrument intended to pinpoint students' learning problems in comprehending the concepts in a certain material [20], [21]. Multiple-choice, interviews, and open-ended questions are among the instruments that can be used in diagnostic tests for detecting misconceptions [22]–[24]. Some types of multiple-choice diagnostic tests are simple multiple-choice, two-tier multiple-choice, three-tier multiple-choice, four-tier multiple-choice, and five-tier multiple choice tests [23], [25].

The five-tier multiple choice test is a development of the four-tier multiple choice where in the fifth tier, a tier is added which contains the source of information used to answer questions. Previous studies that have been developed to find out misconceptions the students have when learning the material of Newton's Law are by the use of three-tier multiple choice and four-tier multiple choice diagnostic tests. The research using the three-tier multiple choice diagnostic test has been developed by several researchers [14], [26], while other researchers have developed the four-tier multiple choice diagnostic test [7], [17], [27]. There has not been found any research reports regarding five-tier multiple choice used in Newton's Law material to identify misconceptions and their causes.

The five-tier diagnostic test compared to other diagnostic tests has some advantages such as it can explain more when identifying student misconceptions and can discover students' level of concept understanding. Students' intensity of utilizing information sources in answering questions can also be shown. So it will be easy for teachers to find solutions to overcome misconceptions that occur [25]. The instruments of five-tier multiple choice have not been designed extensively to identify misconceptions and their causes. The five-tier multiple choice instrument has five levels. Level one covers questions and answers in the form of multiple choice, level two seeks the confidence of the learners in choosing the answers at the previous level, level three explores the reasons why the learners select the answers of the first levels' questions, level four contains the confidence of learners in choosing the answers at level three, and level five identifies the sources used by the learners in solving the questions at both levels one and three. The fifth tier can find out the causes of the misconceptions [12], [18]. The importance of knowing the causes of misconceptions is to be able to find out why misconceptions occur. The causes of misconceptions might come from books used during learning, teachers' explanations, personal thinking, the internet, and others [5]. Table 1 shows the format of the instrument of the multiple choice with five-tiers.

Table 1. Five-tiers multiple choice format [18]

	Nth question	
Tier	Tier type	Value
1	Answer choice	A. (The 1st answer option) B. (The 2nd answer option) C. (The 3rd answer option) D. (The 4th answer option) E. (The 5th answer option)
2	Confidence level in the choice of answer	A. Sure B. Unsure
3	The choice of reason	A. (Reason option 1) B. (Reason option 2) C. (Reason option 3) D. (Reason option 4) E. (Reason option 5)
4	The degree of confidence in the choice of reason	A. Sure B. Unsure
5	Sources of information	A. Book B. Teacher C. Personal thought D. Internet E. Other

Misconceptions that occur in learners, need to be identified to be given solutions so that they do not continue and interfere with the understanding of learners in the next stage of learning [11], [28]. Misconception causes need to be identified to figure out the feasible solutions so that further learning of physics can be carried out [29]. Misconceptions that occur in physics learning have a great impact or influence that can impact subsequent learning [1], [27], [30]. So, an earlier concepts must be understood correctly, before continuing to study the next concept [31].

The students' misconceptions causes can derive from textbooks used during the learning process, from teachers, personal thoughts, and others [5], [32]. Misconceptions owned by the students can be treated if the cause is known [12]. Therefore, misconceptions and their causes need to identify so that in the next lesson, they can be minimized, including in Newton's law material. From the previous discussion of the problems, this study aims to analyze the level of conceptual comprehension of the students in Newton's Law and analyze the causes of misconceptions.

2. RESEARCH METHOD

This research uses a descriptive study with survey methods. The instruments employed in this research were the five-tier multiple choice test and the teacher interview guide. The five-tier multiple choice test was deployed to identify students' conceptual comprehension and to figure out the causes of misconceptions. The teacher interview guide aimed to find out the learning method used by the teacher in delivering Newton's Law material. There were three physics teachers from different school categories as the respondents in this study. The research population is all learners of class X in public high schools in Pasaman Regency, Indonesia for the 2021/2022 academic year. The population used is 12 public high schools in Pasaman Regency, Indonesia. The purposive sampling technique was used to select the samples.

The sampling was based on school accreditation groups and an overall score of all subjects tested in the 2019 National Examination. The number of samples used was 259 students from three public senior high schools representing high, moderate, and low category schools. The whole population in high-category schools is 232 students, in medium-category schools is 86 students, and in low-category schools is 27 students. Therefore, the sample obtained was 259 students that represented high-category schools with as many as 161 students, medium-category schools with as many as 71 students, and low-category schools with as many as 27 students. The number of samples in this research was calculated using the equations of Issac and Michael [33] (1).

$$S = \frac{\lambda^2 \times N \times P \times Q}{d^2(N-1) + \lambda^2 \times P \times Q} \quad (1)$$

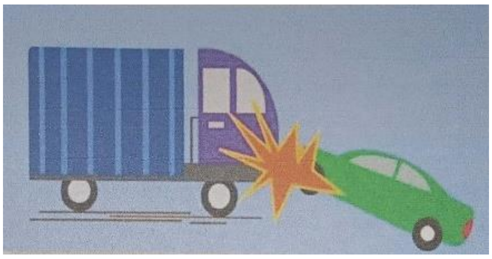
Where, S is number of samples, λ is Chi-squared whose value depends on the degrees of freedom and error. For a degree of freedom of 1 and an error of 5%, the value of chi-squared is 3.841, N is whole population, P is right probability (0.5), Q is error probability (0.5), and d is difference between the average of the samples and the average of population: 0.01; 0.05; and 0.1.

The instrument for gathering the data in this research used an objective/multiple choice test in the form of a five-tier multiple choice. There are 14 questions with a total of seven question indicators, namely investigating the distance of falling objects, investigating the direction of motion of objects on a certain trajectory, explaining Newton's Law I and the nature of inertia, deciphering the forces acting on objects, understanding the concepts in Newton's Law II, analyzing the relationship of forces and masses of objects moving straight in order, and understanding the concept of Newton's Law III. This instrument was obtained from previous researchers [34] which was a four-tier multiple choice.

Then for this study, the fifth tier was added to this four-tier multiple-choice instrument regarding the sources of information obtained by students in answering questions at the previous tier. Sources of information in the fifth tier are to find out the causes of misconceptions. In the fifth tier, students can choose sources of information on answers, with choices: from books, teachers, personal thoughts, and the internet.

The trial of the five-tier multiple choice instrument's questions was conducted in one class with 34 students. The results are used to measure validity, reliability, difficulty level, differentiability of questions, and distractors. Data analysis and processing used statistical package for the social sciences (SPSS) software. The validity test using product moment correlation resulted in all 14 questions in tier-1 and tier-3 being declared valid. The results of Cronbach's alpha reliability test at tier-1 and tier-3 are respectively 0.736 and 0.667 with reliable categories [35]. Validated and reliable instrument was tested on samples to obtain research results. Figure 1 shows one of the five-tier multiple choice questions from the test instrument used in this study.

Look the following picture to answer questions!



The five-tier multiple choice questions (Case example: a sedan and a truck collide head-to-head)

Tier 1	A big truck collided head-to-head with a small sedan. The correct statement describing at the time of the collision is? A. The truck exerts a greater total force on the sedan than the sedan exerts a force on the truck B. The sedan exerts a greater total force on the truck than the truck exerts a force on the sedan C. There is no force exerted by the truck on the sedan and vice versa, the sedan is destroyed just because it blocks the truck's path D. The truck exerts a force on the sedan does not exert a force on the truck E. The truck exerting a force on the sedan equals to the force exerting on the truck
Tier 2	Answer confidence level A. Sure B. Unsure
Tier 3	Reason for choosing the answer A. When a truck collides with a small sedan, there is a pair of action-reaction forces with the same magnitude but in the opposite directions B. When colliding, the truck will exert a greater total force due to the truck's greater mass compared to the sedan's C. When colliding, the sedan will exert a greater total force than the truck so that the resultant force of both cars is equal to zero D. When colliding, both cars immediately stop so that no force is exerted by the two cars E. When colliding, the truck exerts the force against the sedan, but it is not true for the sedan because it stops directly so there is no force acting on it
Tier 4	Confidence level of the reason A. Sure B. Unsure
Tier 5	Sources used to answer the question A. Books B. Teachers C. Personal thoughts D. Internet E. Other

Figure 1. Five-tier multiple choice instrument

The learners' answer data was then analyzed using the criteria for the level of concept understanding, as shown in Table 2. The interpretation of the data obtained from the test results using five-tier multiple choice instruments is grouped into the criteria of understanding the concepts, understanding some of the concepts, not understanding the concepts, and misconceptions. Students' answers based on the previous criteria are presented in (2).

$$P = \frac{S}{J_s} \times 100\% \quad (2)$$

Where, P is the percentage of the number of students who experience understanding the concepts, understanding some of the concepts, not understanding the concepts or misconceptions, S is the number of students who understand the concepts, understand some concepts, do not understand the concepts or have misconceptions, and Js is the number of students who take the test. Based on students' answers, the level of understanding of the concept and the causes of misconceptions were categorized as shown in Table 2.

Table 2. Interpretation of learners' answers [32]

Tier I	Tier II	Tier III	Tier IV	Tier V	Conception level and its causes
				Book	M-Book
				Teacher	M-Teacher
				Personal thought	M-Personal thought
Wrong	Sure	Wrong	Sure	Friend	M-Friend
				Internet	M-Internet
				Book	UC-Book
				Teacher	UC-Teacher
				Personal thought	UC-Personal thought
Correct	Sure	Correct	Sure	Friend	UC-Friend
				Internet	UC-Internet
Correct	Sure	Correct	Unsure	Book	PCU-Book
Correct	Unsure	Correct	Sure		
Correct	Unsure	Correct	Unsure	Teacher	PCU-Teacher
Correct	Sure	Wrong	Sure		
Correct	Sure	Wrong	Unsure	Personal thought	PCU-Personal thought
Correct	Unsure	Wrong	Sure		
Correct	Unsure	Wrong	Unsure	Friend	PCU-Friend
Wrong	Sure	Correct	Sure		
Wrong	Sure	Correct	Unsure		
Wrong	Unsure	Correct	Sure	Internet	PCU-Internet
Wrong	Unsure	Correct	Unsure		
				Book	NUC-Book
				Teacher	NUC-Teacher
Wrong	Sure	Wrong	Unsure	Personal thought	NUC-Personal thought
Wrong	Unsure	Wrong	Sure	Friend	NUC-Friend
Wrong	Unsure	Wrong	Unsure	Internet	NUC-Internet

M=Misconception; UC=Understand the concepts; PCU=Partial concept understanding; NUC=Not understanding the concept

3. RESULTS AND DISCUSSION

Based on the data from the study using the five-tier multiple choice instrument on Newton's Law material, the research results can be classified into the level of students' concept comprehension and the causes of the misconceptions. The data on the level of students' concept understanding can be grouped into two, namely, based on school categories and question indicators. In general, Figure 2 shows the students' concept understanding for all school categories.

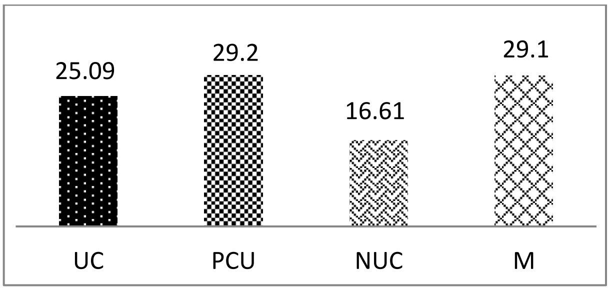


Figure 2. Concept understanding

3.1. Students' concept understanding

3.1.1. Conceptual understanding by school categories

The data of the students' answers in this study were processed and presented based on conceptual understanding and school categories. The schools used in the sample were schools with high, medium, and low categories. The level of students' understanding of concepts, namely the categories of understanding the concepts (UC), partial concept understanding (PCU), not understanding the concept (NUC), and misconception (M), was analyzed based on a combination of student answers as shown in Table 2. Based on these data, it can be seen the comparison of the students' level of understanding of the concept in each school category. Figure 3 shows the level of conceptual understanding of the learners based on the school category.

Figure 3 shows the percentages of students' conceptual understanding level for each school category. It can be seen that high category schools have a greater percentage of students who UC than other category schools. Schools in the low category have a higher level of M than schools in the high and medium categories. Schools with a high category have a lower percentage of M.

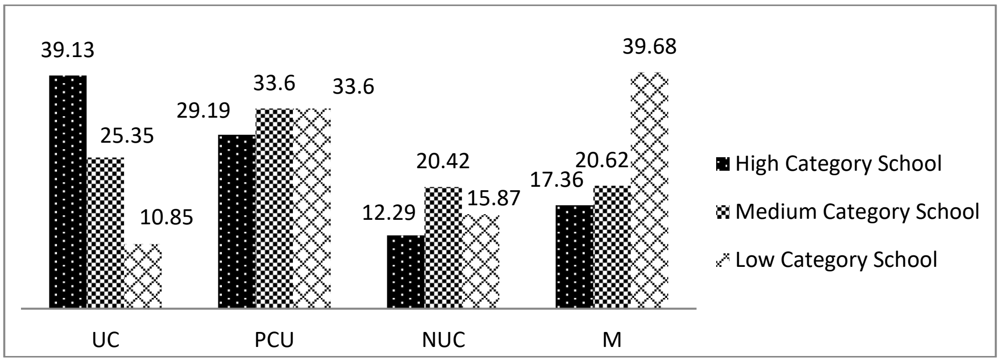


Figure 3. Conceptual understanding by school categories

The results of data analysis based on the level of schools' UC are experienced more by students in high category schools compared to medium and low-category schools, whereas low category schools experience more M than medium and high-category schools. This might indicate the low quality of learning in low-category schools. The quality of learning here can be in the form of learning methods used or applied by educators when teaching. The use of appropriate learning method will make it easier for students to understand the concepts given or conveyed. On the other hand, if the learning method used is inappropriate, it will make the concepts difficult to understand or may result in misconceptions. In addition, another factor that makes students experience not understanding the concepts and misconceptions is the low interest in learning. Learners who do not have an interest or motivation to learn are less likely to pay attention and focus on the lessons provided by the teacher.

Based on the interviews, teachers in high and middle school categories used a combined method in teaching Newton’s Law material. The method covers the lecture, discussion, and question and answer methods. Therefore, the students can more easily understand the concepts given by the teachers. Through discussion as well as question and answer, it can increase understanding of the concept. The learning method used by educators in schools with low categories is the lecture method or teacher centered only, and consequently, the students do not pay attention to the learning provided by the teachers. This situation causes students to experience misconceptions more easily. Involving learners in discovering concepts does not yet exist, such as conducting experiments. Improper learning methods can lead to misconceptions in learners [27]. Learning that is dominantly centered on the teacher can cause students' abilities to be less trained, so that students have difficulty understanding concepts and tend to experience misconceptions [36]. The learning process that uses the experimental method will encourage students to find the correct learning concept and based on scientific facts so as to increase understanding of the concept [37].

3.2. Conceptual understanding by question indicators

3.2.1. Category of understanding the concepts

Based on question indicators, the percentage of students who understand the concepts for the three school categories is shown in Table 3. It can be seen that for students who understand the concepts, if the three school categories are compared, schools with high categories have the highest percentage compared to the medium and low-school categories in almost all question indicators, except for the question indicator “Deciphering the forces that work on objects”. The students who experienced the most understanding of the concept in the indicator were in the category of medium schools.

Table 3. Data on students who understand concepts based on question indicators

No	Competency achievement indicators	Number of questions	Question number	School categories High (%)	Medium (%)	Low (%)
1.	Investigating the distance at which objects fall	1	1	83.85	59.15	25.93
2.	Investigating the motion direction of objects on a specific trajectory	4	3, 4, 5, 9	55.90	31.34	12.96
3.	Explaining Newton’s Law I and the nature of inertia	1	6	29.19	11.27	3.7
4.	Deciphering the forces acting on objects	3	7, 8, 10	10.56	21.13	11.11
5.	Understanding the concept on Newton’s Law II	1	13	26.09	21.13	7.4
6.	Analyzing the relationship of forces and masses of objects moving straight in order	1	12	29.19	8.45	3.7
7.	Understanding the concept of Newton’s Law III	3	2, 11, 14	41.41	22.07	8.67
	Average			39.46	24.93	10.49

3.2.2. Category of partial concept understanding

Based on question indicators, the percentage of students who understand some of the concepts for the three school categories is can be seen in Table 4. The table informs that students who experience partial concept understanding are mostly experienced by students in schools with medium and low categories. High and medium category school students who experienced the most partial concept understanding were in the question indicator "deciphering the forces acting on the objects" and the smallest percentage on the question indicator "investigating the distance of falling objects". Low-category school students who experienced a partial concept understanding were most in the indicators of "investigating the direction of motion of objects on the trajectory" and the least in the indicators of the questions of "analyzing the relationship of force and mass of objects moving straight in order".

Students who understand the concept partially can be interpreted that they already understand or has understood the concept in the material, but still partly. Students who experience a partial understanding of concepts can be seen from the answers given to tier-1 and tier-3 questions. Students who experience a perfect understanding of concepts will have the correct answer in tier-1 and tier-3, but for students who understand the concept partially, it is only true in one of the tiers, namely between tier-1 and tier-3.

Table 4. Data on the percentage of students who understand concepts in part based on question indicators

No	Competency achievement indicators	Number of questions	Question number	School categories		
				High (%)	Medium (%)	Low (%)
1.	Investigating the distance at which objects fall	1	1	3.73	18.31	29.63
2.	Investigating the motion direction of objects on a specific trajectory	4	3, 4, 5, 9	33.39	35.56	39.82
3.	Explaining Newton's Law I and the nature of inertia	1	6	22.36	33.8	29.63
4.	Deciphering the forces acting on objects	3	7, 8, 10	38.71	42.25	35.80
5.	Understanding the concept on Newton's Law II	1	13	21.11	32.39	33.33
6.	Analyzing the relationship of forces and masses of objects moving straight in order	1	12	30.43	26.76	18.52
7.	Understanding the concept on Newton's Law III	3	2, 11, 14	27.12	30.05	27.16
	Average			25.26	31.30	30.56

3.2.3. Category of not understanding the concept

Based on question indicators, the percentage of students who do not understand the concepts for the three school categories can be seen in Table 5. The table shows that students who do not understand the concepts are mostly experienced by students in schools with medium and low categories. Medium and low category school students who do not understand the concepts had the highest percentage in the indicators of the question "analyzing the relationship of force and mass of objects moving straight in order," namely 29.58% and 29.63%. The high category school learners who experienced the most unfamiliar with the concepts are in the material "understanding the concepts in Newton's Law II."

Table 5. Data on the percentage of students who do not understand the concepts based on question indicators

No	Competency achievement indicators	Number of questions	Question number	School categories (%)		
				High	Medium	Low
1.	Investigating the distance at which objects fall	1	1	5.59	11.27	11.11
2.	Investigating the motion direction of objects on a specific trajectory	4	3, 4, 5, 9	5.28	16.90	16.67
3.	Explaining Newton's Law I and the nature of inertia	1	6	18.01	21.13	3.7
4.	Deciphering the forces acting on objects	3	7, 8, 10	17.39	21.13	12.34
5.	Understanding the concept on Newton's Law II	1	13	21.12	18.31	14.81
6.	Analyzing the relationship of forces and masses of objects moving straight in order	1	12	15.53	29.58	29.63
7.	Understanding the concept on Newton's Law III	3	2,11,14	12.84	24.88	19.75
	Average			13,68	20.46	15.43

3.2.4. Category of misconception

Based on question indicators, the percentage of students who experience misconceptions for the three school categories is shown in Table 6. The table shows that for learners who experience misconceptions, if the three school categories are compared, then schools with low categories have the highest percentage of misconceptions compared to high and medium-category schools for all question indicators. Students in the high-category schools experienced the most misconceptions in the question indicator "deciphering the forces acting on the objects" and the least in the question indicator "investigating the motion direction of the objects on the trajectory."

The results of this study support Bayraktar's research which stated that the most misconceptions happened in the concept of deciphering the forces on objects [38]. Students in medium-category schools experienced the most misconceptions in the indicator of the question "analyzing the relationship of the force and mass of objects moving straight in order" and at least in the indicator of the question of "investigating the distance of at which objects fall." The results of this study are also in line with a study conducted by Reyes and Kurniawan which stated that 48% of students experienced a misconception about determining the mass of an object [39], [40]. Students in low-category schools experienced the most misconceptions in Newton's Law I material. Rusilowati *et al*. stated the learners' understanding which experienced the greatest misconceptions was in the material of Newton's Law I [26].

Table 6. Data on the percentage of students who have misconceptions based on question indicators

No	Competency achievement indicators	Number of questions	Question number	School categories (%) High	Medium	Low
1.	Investigating the distance at which objects fall	1	1	6.83	11.27	33.33
2.	Investigating the motion direction of objects on a specific trajectory	4	3, 4, 5, 9	5.43	16.20	30.56
3.	Explaining Newton's Law I and the nature of inertia	1	6	30.43	33.8	62.96
4.	Deciphering the forces acting on objects	3	7, 8, 10	33.33	15.49	40.74
5.	Understanding the concept on Newton's Law II	1	13	31.67	28.16	33.33
6.	Analyzing the relationship of forces and masses of objects moving straight in order	1	12	24.84	35.21	48.15
7.	Understanding the concept on Newton's Law III	3	2, 11, 14	18.63	23.01	44.44
	Average			21.59	23.31	41.93

According to Sundaygara *et al*. in their research, students' understanding of Newton's Law material is relatively low, such understanding concepts at 21%, understanding some concepts at 16%, not understanding concepts at 9%, and misconceptions at 54% [27]. The results of the study obtained in schools with low categories are in line with previous studies which showed that the misconceptions had by students were greater than students who understood concepts and the material that experienced the most misconceptions, namely the material of Newton's Law I with 62.96%. Schools in the medium category that have experienced the most misconceptions are in the indicators about analyzing the relationship of force and mass of objects that move straight in order, while for high-category schools the most misconceptions occur in the indicators describing the forces acting on objects. From the research results obtained, schools with low categories have the highest percentage of misconceptions compared to high and medium-category schools, whereas the highest level of understanding of concepts is found in high categories schools and followed by medium and low-category schools.

Based on the research results obtained, in general, schools with low categories have the highest percentage of misconceptions compared to high and medium-category schools. As for the highest level of understanding of the concept, it is found in schools with high categories and followed by medium and low-category schools, except for question number 10 with the question indicator "describing the forces that act on objects". In this problem, high-category school students experience more misconceptions than those who understand concepts. Medium-category school learners experience fewer misconceptions about the concept of deciphering the forces acting on objects. Based on interviews with teachers who teach in medium-category schools when teaching Newton's Law material on the concept of force acting on objects, teachers focus more on students in understanding how to decipher the forces that work on objects. In other words, the teacher gives extra instruction to learners in understanding the forces that act on the objects, so that the learner can understand the material better. As a result, it can reduce the occurrence of misconceptions.

3.3. The causes of students' misconceptions

The causes of the misconception experienced by the students can be identified through the fifth-tier. The students' misconceptions caused can be seen in Figure 4. It can be seen that the causes of misconceptions in learners are mostly caused by personal thinking for all school categories. This means that all levels of school, namely low, medium, and high are experiencing misconceptions caused by personal thoughts. The sources of misconception's causes in students can be caused by books used during learning, explanations given by teachers, personal thoughts, the internet, and others. The causes of misconceptions in high-category school students from personal thinking at an average of 87.64%, medium schools by 95.12%, and low schools by 68%. The personal thoughts of learners are the source of the most causes. This is also supported by several researches [12], [39], [41], [42], which identified misconceptions and their causes. The results of Inggit's research on the causes of misconceptions are most caused by students' thoughts, namely 80%; in Bayuni's research, the most are caused by personal thoughts 22%; and in Hermanto's research, the most causes of misconceptions come from the thoughts of students, as much as 39%.

The causes of misconceptions derived from personal thinking can be caused by initial knowledge, learners' associative thinking, humanistic thinking, incomplete reasoning, and wrong intuition [5], [10]. Learners who have initial knowledge of a concept that has not been learned under the guidance of the teacher often result in misconceptions. For example, in the material of Newton's Law III, students have the initial knowledge that an object that has a large mass will have a greater total force than an object with a small mass. Misconceptions caused by personal thinking also come from the learner's associative thinking towards daily terms, for example, the forces are associated with movement/action and then learners assume all forces can cause motion. This indicates that there is a need for improvements in the learning process and solutions to overcome the occurrence of misconceptions caused by the personal thoughts of students so that misconceptions that occur can be minimized. An alternative solution that can be provided in overcoming misconceptions is the implementation of a cognitive conflict-based learning (CCBL) model [43], [44].

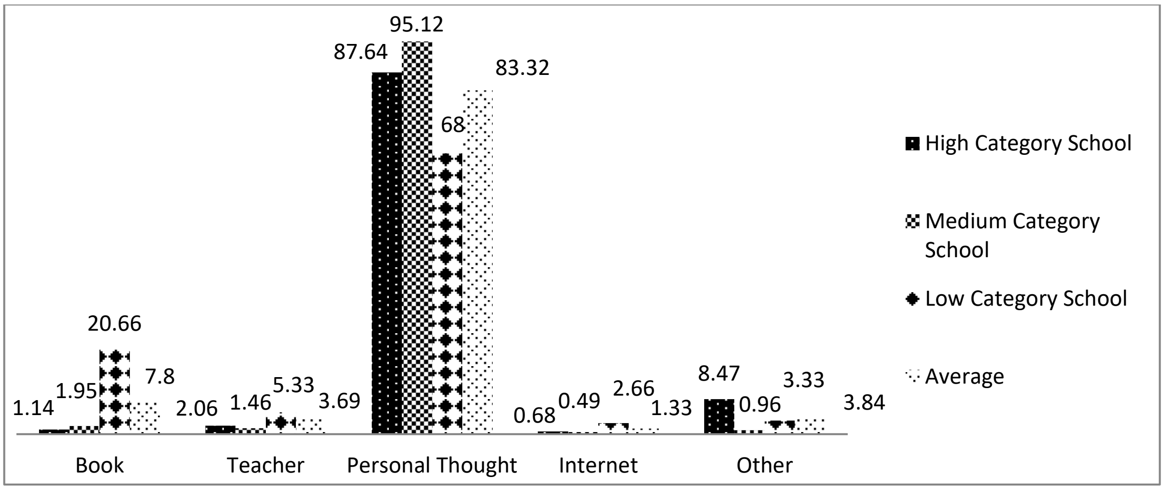


Figure 4. Causes of misconceptions

4. CONCLUSION

Based on the results of research on analysis of misconceptions and their causes in Newton's Law material using five-tier multiple-choice instruments in Pasaman Regency High Schools, it can be concluded that the highest misconception of high-category school students occurred in the concept of deciphering the forces acting on objects (33.33%). The highest misconception among medium-category school learners occurred in the concept of investigating the direction of motion of objects on a particular trajectory (35.21%). The highest misconceptions occurred in low-category school learners on the concept of explaining Newton's Law I and the nature of inertia (62.96%). Misconceptions that occur in low-category schools are more prevalent than in other category schools. The causes of misconceptions in students are mostly caused by the personal thoughts of students and then followed by books, teachers, and the internet sources. These results indicate that misconceptions may occur in students in all school categories and are predominantly caused by personal thoughts. Therefore, it is suggested that teachers engage students in learning by conducting physics experiments to construct concepts to avoid misconceptions.

REFERENCES

[1] F. Mufit, "A study about understanding the concept of force and attitude towards learning physics on first-year students in the course of general physics; as preliminary investigation in development research," *Proceeding the 4th SEA-DR 2016*, 2016, doi: https://doi.org/10.31227/osf.io/8n6ep.

[2] D. U. Rahmawati, Jumadi, H. Kuswanto, and I. A. Oktaba, "Identification of students' misconception with isomorphic multiple choices test on the force and newton's law material," *Journal of Physics: Conference Series*, vol. 1440, no. 1, p. 012052, Jan. 2020, doi: 10.1088/1742-6596/1440/1/012052.

[3] R. Zahro, Jumadi, I. Wilujeng, and H. Kuswanto, "The effect of web-assisted problem based learning model on physics conceptual understanding of 10th grade students," *Journal of Physics: Conference Series*, vol. 1233, no. 1, p. 012058, Jun. 2019, doi: 10.1088/1742-6596/1233/1/012058.

[4] R. Puspitasari, F. Mufit, and Asrizal, "Conditions of learning physics and students' understanding of the concept of motion during the covid-19 pandemic," *Journal of Physics: Conference Series*, vol. 1876, no. 1, p. 012045, Apr. 2021, doi: 10.1088/1742-6596/1876/1/012045.

[5] P. Suparno, *Misconceptions and concept change in physics education*. Jakarta: Grasindo (in Indonesian), 2013.

[6] I. Kibirige and D. Mamashela, "High school students' misconceptions about force: what changed the flipped class experience?" *Journal for the Education of Gifted*, vol. 10, no. 1, pp. 99–120, 2022.

[7] L. Maharani, D. I. Rahayu, E. Amaliah, R. Rahayu, and A. Saregar, "Diagnostic test with four-tier in physics learning: case of misconception in Newton's Law material," *Journal of Physics: Conference Series*, vol. 1155, p. 012022, Feb. 2019, doi: 10.1088/1742-6596/1155/1/012022.

[8] Y. Deringöl, "Misconceptions of primary school students about the subject of fractions: views of primary teachers and primary pre-service teachers," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 8, no. 1, p. 29, Mar. 2019, doi: 10.11591/ijere.v8i1.16290.

[9] Ü. Turgut, F. Gürbüz, and G. Turgut, "An investigation 10th grade students' misconceptions about electric current," *Procedia - Social and Behavioral Sciences*, vol. 15, pp. 1965–1971, 2011, doi: 10.1016/j.sbspro.2011.04.036.

[10] S. Soeharto and B. Csapó, "Evaluating item difficulty patterns for assessing student misconceptions in science across physics, chemistry, and biology concepts," *Heliyon*, vol. 7, no. 11, p. e08352, Nov. 2021, doi: 10.1016/j.heliyon.2021.e08352.

[11] Z. D. Kirbulut and O. Geban, "Using three-tier diagnostic test to assess students' misconceptions of states of matter," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 10, no. 5, Dec. 2014, doi: 10.12973/eurasia.2014.1128a.

[12] T. C. Bayuni, W. Sopandi, and A. Sujana, "Identification misconception of primary school teacher education students in changes of matters using a five-tier diagnostic test," *Journal of Physics: Conference Series*, vol. 1013, p. 012086, May 2018, doi: 10.1088/1742-6596/1013/1/012086.

[13] D. Setiawan and N. Faoziyah, "Development of a five-tier diagnostic test to reveal the student concept in fluids," *Physics Communication*, vol. 4, no. 1, pp. 6–13, 2020, doi: https://doi.org/10.15294/physcomm.v4i1.21181.

[14] E. Sulistri and L. Lisdawati, "Using three-tier test to identify the quantity of student that having misconception on Newton's Laws of motion concept," *JIPF (Jurnal Ilmu Pendidikan Fisika)*, vol. 2, no. 1, p. 4, Oct. 2017, doi: 10.26737/jipf.v2i1.195.

[15] Ö. Keles, H. Ertas, N. Uzun, and M. Cansiz, "The understanding levels of preservice teachers' of basic science concepts' measurement units and devices, their misconceptions and its causes," *Procedia - Social and Behavioral Sciences*, vol. 9, pp. 390–394, 2010, doi: 10.1016/j.sbspro.2010.12.170.

[16] F. Mufit, Festiyed, A. Fauzan, and Lufri, "The application of real experiments video analysis in the CCBL model to remediate the misconceptions about motion's concept," *Journal of Physics: Conference Series*, vol. 1317, p. 012156, Oct. 2019, doi: 10.1088/1742-6596/1317/1/012156.

[17] I. Kaniawati, N. J. Fratiwi, A. Danawan, I. Suyana, A. Samsudin, and E. Suhendi, "Analyzing students' misconceptions about Newton's Laws through four-tier Newtonian test (FTNT)," *Journal of Turkish Science Education*, vol. 16, no. 1, 2019.

[18] A. S. U. Putra, I. Hamidah, and Nahadi, "The development of five-tier diagnostic test to identify misconceptions and causes of students' misconceptions in waves and optics materials," *Journal of Physics: Conference Series*, vol. 1521, no. 2, p. 022020, Apr. 2020, doi: 10.1088/1742-6596/1521/2/022020.

[19] I. P.-A. Cheong, M. Johari, H. Said, and D. F. Treagust, "What do you know about alternative energy? Development and use of a diagnostic instrument for upper secondary school science," *International Journal of Science Education*, vol. 37, no. 2, pp. 210–236, Jan. 2015, doi: 10.1080/09500693.2014.976295.

[20] S. Kantahan, P. Junpeng, S. Punturat, K. N. Tang, P. Gochyyev, and M. Wilson, "Designing and verifying a tool for diagnosing scientific misconceptions in genetics topic," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 9, no. 3, p. 564, Sep. 2020, doi: 10.11591/ijere.v9i3.20544.

[21] N. J. Fratiwi, I. Kaniawati, E. Suhendi, I. Suyana, and A. Samsudin, "The transformation of two-tier test into four-tier test on Newton's laws concepts," in *AIP Conference Proceedings*, 2017, p. 050011, doi: 10.1063/1.4983967.

[22] S. Ünal, B. Coştu, and A. Ayas, "Secondary school students' misconceptions of covalent bonding," *Journal of Turkish Science Education*, vol. 7, no. 2, 2010.

[23] D. Kaltakci Gurel, A. Eryilmaz, and L. C. McDermott, "A review and comparison of diagnostic instruments to identify students' misconceptions in science," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 11, no. 5, Oct. 2015, doi: 10.12973/eurasia.2015.1369a.

[24] D. Kaltakci-Gurel, A. Eryilmaz, and L. C. McDermott, "Development and application of a four-tier test to assess pre-service physics teachers' misconceptions about geometrical optics," *Research in Science & Technological Education*, vol. 35, no. 2, pp. 238–260, Apr. 2017, doi: 10.1080/02635143.2017.1310094.

[25] H. M. Dirman, F. Mufit, and F. Festiyed, "Review and comparison of four-tier multiple choice and five-tier multiple choice diagnostic tests to identify mastery of physics concepts," *Jurnal Penelitian Pendidikan IPA*, vol. 8, no. 1, pp. 1–12, Jan. 2022, doi: 10.29303/jppipa.v8i1.838.

[26] A. Rusilowati, R. Susanti, T. Sulistyaningsing, T. S. N. Asih, E. Fiona, and A. Aryani, "Identify misconception with multiple choice three tier diagnostik test on newton law material," *Journal of Physics: Conference Series*, vol. 1918, no. 5, p. 052058, Jun. 2021, doi: 10.1088/1742-6596/1918/5/052058.

[27] C. Sundaygara, L. A. R. P. Gusi, H. Y. Pratiwi, H. D. Ayu, A. Jufriadi, and M. N. Hudha, "Identification students' misconception using four-tier diagnostic test on Newton Law subject," *Journal of Physics: Conference Series*, vol. 1869, no. 1, p. 012157, Apr. 2021, doi: 10.1088/1742-6596/1869/1/012157.

[28] D. Çelikler and Z. Aksan, "Determination of knowledge and misconceptions of pre-service elementary science teachers about the greenhouse effect by drawing," *Procedia - Social and Behavioral Sciences*, vol. 136, pp. 452–456, Jul. 2014, doi: 10.1016/j.sbspro.2014.05.355.

[29] F. Salmadhia, H. Rusnayati, and W. Liliawati, "Five-tier geometrical optics test feasibility to identify misconception and the causes in high school students," *Berkala Ilmiah Pendidikan Fisika*, vol. 9, no. 2, p. 141, Jul. 2021, doi: 10.20527/bipf.v9i2.8874.

[30] I. M. Hermanto, M. Muslim, A. Samsudin, and J. Maknun, "K-10 students' conceptual understanding on Newton's laws: current and future directions," *Journal of Physics: Conference Series*, vol. 1280, no. 5, 2019, doi: 10.1088/1742-6596/1280/5/052059.

[31] Y. M. Cholily and B. I. Suwandayani, "Understanding the concept of the Pi (π) number for pre-service teacher," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 10, no. 4, p. 1366, Dec. 2021, doi: 10.11591/ijere.v10i4.21674.

[32] S. L. Handayani and A. Arifin, "Analysis students' misconception in optical material using three tier multiple choice diagnostic test," *Physics Education Research Journal*, vol. 3, no. 2, pp. 75–84, Aug. 2021, doi: 10.21580/perj.2021.3.2.8703.

[33] S. Nugroho, A. Nasrulloh, T. H. Karyono, R. Dwihandaka, and K. W. Pratama, "Effect of intensity and interval levels of trapping circuit training on the physical condition of badminton players," *Journal of Physical Education and Sport*, vol. 21, no. 3, pp. 1981–1987, 2021, doi: 10.7752/jpes.2021.s3252.

[34] F. Mufit and S. Syamsidar, "Development of four-tier multiple choice test instrument to identify students' concept understanding of Newton's Law material," *Jurnal Ilmiah Pendidikan Fisika*, vol. 7, no. 2, 2022, doi: https://dx.doi.org/10.26737/jipf.v7i2.2369.

[35] A. Ahdika, "Improvement of quality, interest, critical, and analytical thinking ability of students through the application of research based learning (RBL) in introduction to stochastic processes subject," *International Electronic Journal of Mathematics Education*, vol. 12, no. 2, pp. 167–191, May 2017, doi: 10.29333/iejme/608.

[36] I. Rosita, W. Liliawati, and A. Samsudin, "Development of five-tier Newton's Laws test (5TNLT) instrument to identify students' misconceptions and causes of misconceptions," (in Indonesian), *Jurnal Pendidikan Fisika dan Teknologi*, vol. 6, no. 2, pp. 297–306, Dec. 2020, doi: 10.29303/jpft.v6i2.2018.

[37] J. Capriconia and F. Mufit, "Analysis of concept understanding and students' attitudes towards learning physics in material of straight motion," *Jurnal Penelitian Pendidikan IPA*, vol. 8, no. 3, pp. 1453–1461, Jul. 2022, doi: 10.29303/jppipa.v8i3.1381.

[38] S. Bayraktar, "Misconceptions of Turkish pre-service teachers about force and motion," *International Journal of Science and Mathematics Education*, vol. 7, no. 2, pp. 273–291, Apr. 2009, doi: 10.1007/s10763-007-9120-9.

[39] Y. Kurniawan, "Investigation of the misconception in Newton II Law," *Jurnal Pena Sains*, vol. 5, no. 1, p. 11, Apr. 2018, doi: 10.21107/jps.v5i1.3879.

[40] R. Rosiqoh and E. Suhendi, "Using Rasch model analysis to analyse students' mastery of concept on newton law," *Journal of Physics: Conference Series*, vol. 1731, no. 1, p. 012077, Jan. 2021, doi: 10.1088/1742-6596/1731/1/012077.

[41] S. M. Inggit, W. Liliawati, and I. Suryana, "Identification of misconceptions and their causes using the five-tier fluid static test (5TFST) instrument for grade XI high school students," (in Indonesian), *Journal of Teaching and Learning Physics*, vol. 6, no. 1, pp. 49–68, Feb. 2021, doi: 10.15575/jotalp.v6i1.11016.

[42] A. Halim, D. Lestari, and Mustafa, "Identification of the causes of misconception on the concept of dynamic electricity," *Journal of Physics: Conference Series*, vol. 1280, no. 5, p. 052060, Nov. 2019, doi: 10.1088/1742-6596/1280/5/052060.

[43] F. Mufit, A. Asrizal, R. Puspitasari, and A. Annisa N, "Cognitive conflict-based e-book with real experiment video analysis integration to enhance conceptual understanding of motion kinematics," *Jurnal Pendidikan IPA Indonesia*, vol. 11, no. 4, pp. 626–639, Dec. 2022, doi: 10.15294/jpii.v11i4.39333.

[44] F. Mufit, F. Festiyed, A. Fauzan, and L. Lufri, "The effect of cognitive conflict-based learning (CCBL) model on remediation of misconceptions," *Journal of Turkish Science Education*, vol. 20, no. 1, pp. 26–49, Mar. 2023, doi: 10.36681/tused.2023.003.

BIOGRAPHIES OF AUTHORS

Rania Atara Isra is a teacher and holds a Bachelor of Physics Education in the Department of Physics, Faculty of Mathematics and Science, Universitas Negeri Padang, Indonesia. She actively conducts research with supervisors, especially in the field of understanding concepts and misconceptions in learning physics. She can be contacted at email: raniania125@gmail.com.

Fatni Mufit is a Senior Assistant Professor at the Physics Department, Faculty of Math and Science, Universitas Negeri Padang. Indonesia. She obtained her Doctoral degree in Science Education from Universitas Negeri Padang. Her areas of research interest include Physics Education and Learning, the development of learning models and media, the misconception and conceptual understanding. She can be contacted at email: fatni_mufit@fmipa.unp.ac.id.