Minimizing Physics Students Misconceptions Through Using Investigation-Based Group Inquiry Model Worksheets

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Abstract. This research aims to minimize misconceptions among Physics students through investigation-based group inquiry worksheets on the concept of Newton^s laws of motion. This type of research is quasi-experimental using a one-group pretest-posttest design. Sampling was carried out using a cluster sampling technique for 1 class. The research instrument used in this study was an open-ended multiple-choice test accompanied by a CRI column. The findings of this research show that before the treatment the level of student misconceptions was 53%, after being given treatment the level of student misconceptions became 36%. These results illustrate that investigation-based group inquiry model worksheets can minimize Physics students^ misconceptions by 17% regarding the concept of Newton^s laws of motion.

Keywords: Inquiry Group; Investigation; Minimization; Misconceptions; Worksheets

1 Introduction

Student learning outcomes in Physics at the senior high school level in Indonesia are still low. Factors that cause low physics learning outcomes include students experiencing misconceptions[1]. The low ability of high school students in Indonesia is reflected in the ability of Indonesian high school students to work on PISA questions, which is ranked 74 out of 79 countries [2]; PISA questions that students can work on are in the aspects of memory, understanding, and application. The low ability of students has an impact on the high level of students' physics misconceptions. Several research results in several senior high schools show that students with low cognitive abilities still have quite high levels of [3–5]. The occurrence of misconceptions in students becomes a source of doubt for students when they conflict with new concepts that they have learned which then become doubtful [6]. Misconceptions in Physics

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arise not only from students but also from teachers, textbooks, and evaluation tools. When teachers lack mastery of the material or have incorrect understandings of concepts, they can inadvertently lead students to develop misconceptions. Generally, research identifies the students' own thinking processes as the primary cause of these conceptual errors. Misconceptions span all Physics concepts. Out of 700 studies on misconceptions, 300 focused on mechanics, 159 on electricity, 70 on heat, optics, and material properties, and 35 on earth and space science and modern Physics. The alternative concepts (misconceptions) occur in all fields of physics[7]. The high level of misconceptions among students at the high school level in Indonesia also occurs in first-year students at several universities. The high level of misconceptions among first-year students will have difficulty understanding the concept of advanced teaching materials that are higher and more complex. Physics is a part of science that studies phenomena and natural phenomena in inanimate objects empirically, logically, systematically and rationally involving scientific processes [8]. One of the principles of physics that is always related to everyday life is Newton's Law. Newton's Law is three laws of physics that describe the forces acting on moving objects, such as the fall of an object downwards due to the gravitational force acting on the object. In this material, there is a relationship between concepts and other conceptions that if there is an error in one of the concepts, it will cause an error in applying the concept of Newton's Law.

Some ways to reduce student misconceptions, it is essential to identify and articulate the misconceptions they have, actively seek out these misconceptions, and apply the appropriate interventions to address them. In this study, efforts to minimize student misconceptions were made using the Investigation-Based Group Inquiry Model Worksheet. This worksheet combines elements from both the inquiry training learning model and the group investigation model. It comprises six learning phases: orientation to phenomena or fact-based situations, hypothesizing solutions, collecting data and verifying conditions and situations, providing experimental justification, analyzing considerations, and verifying and analyzing the achievement process. [9]. The strengths of this Investigation-Based Group Inquiry Model Worksheet include the formulation of the Grand Hypothesis. The grand hypothesis is formed through discussion and planning based on the individual hypotheses of group members [9]. Another strength is in the collection of data evidence - verification of conditions and situations by involving the study of various learning sources such as textbooks, teaching materials, research results, relevant internet sites for the purposes of proving grand hypotheses. Students' experiences from various sources of data evidence will improve students' understanding of physics concepts, and can reduce the level of students' physics misconceptions.

2 Methods

This research method is a quasi-experimental using one group pretest-posttest design. The subjects of the study were 30 first-year students of the Physics Education Study Program, Universitas Negeri Medan, Academic Year 2023/2024. The object of the study was minimizing misconceptions of Newton's laws of motion through the use of the Investigation-Based Group Inquiry Model Worksheet. The instrument used in this study was an objective test of the true-false type totaling 15 questions. Each test is accompanied by the Cartainty of Response Index (CRI) method in the form of student responses.

Table 1. CRI Scale Criterion

CRI (Certainty of Response Index)	Confidence Level
0	Totally Guess Answer
1	Almost Guess
2	Not Sure
3	Sure
4	Almost Sure
5	Certain

Three tier test, namely the content tier which measures the respondent's ability to the concept, the reason tier to see the reasons behind the answers given to the content tier and the certainty response index which measures how confident the respondent is in the answers at the first and second levels [10]. The data analysis technique of this research starts from determining the value of student responses based on the CRI scale compiled [11]shown in Table 1. The second step is determining the scale value for CRI, then determining the category of student answers whether they are misconceptions or not using the CRI matrix table shown in Table 2. Determining the minimization of student misconceptions uses the percentage technique by calculating the difference in the percentage of pretest and posttest misconceptions.

Table 2. CRI Matrix

Answer Criteria	**Low CRI (<2.5)**	**High CRI (> 2.5)**
Correct	Correct answer Low CRI means not knowing the concept	Correct answer and high CRI means misconception occurs
Wrong	Wrong answer and having a low score means not knowing the concept	Wrong answer but high GRI means there is a misconception

3 Results and Discussions

The results of the study related to students' misconceptions before and after the learning treatment using the Investigation-Based Group Inquiry Model Worksheet are presented in the form of Figures 1 and 2. The results of the recapitulation of the average percentage of students' misconceptions for each question item on the concept of Newton's law of motion shown in Figure 1 aim to see an overall picture of the percentage level and changes in students' misconceptions regarding the question items on the concept of Newton's law of motion before and after the learning treatment.

The pretest results showed that only three questions had a percentage below 50%, namely questions no. 6 (27%), 7 (30%) and 8 (47%), while the other 12 questions had a percentage of 50% and above, namely questions no. 1, 2, 3, 4, 5, 9, 10, 11, 12, 13, 14, and 15. In general, students already understand Newton's second law; the relationship between acceleration, mass, and resultant force can be described correctly. However, some students still do not understand the relationship between the direction of force, friction and resultant force acting on an object.

Some of the reasons why students misconceive Newton's second law include the friction force on an object is considered not to affect the resultant force of the object acting on the object, they only assume that friction functions to slow down the movement of the object. Some student answers explain that the direction of the force on an object does not affect the acceleration of the object, they explain that the acceleration of the object is not influenced by the resultant force but is influenced by the magnitude of the force. They do not describe the magnitude of the force that is meant as the magnitude of the resultant force or not. Another factor that causes students' misconceptions about Newton's II law is that they state that the mass of a moving object is not inversely proportional to its acceleration.

There are 12 questions with a percentage of misconceptions of 50% and above, there are 3 questions with a percentage of misconceptions of 60%, namely questions number 2, 5, and 14. Question number 2 (63%) is related to the concept of Newton's first law. Students conclude that a stationary object, for example an object on a table, is because there is no force acting on the object. The findings of the misconception research [12]. stated that there is no force acting on a stationary object. Lack of understanding that all objects on the surface of the earth experience gravitational force which is often called gravity or object weight. Lack of understanding of the concept of normal force and the concept of gravity and normal force. Also their understanding of the concept of Newton's first law which states: the resultant force acting on an object is zero, then the object moves in a straight line (v constant or a = 0), or the object is still (v = 0). Students argue that zero force response is the same as no force. Question number 5 has a percentage of student misconceptions reaching 60%. This question is related to the analysis of Newton's first law for motorcyclists who are passing on a straight downhill road. Students do not understand that the force that controls the speed or acceleration of a motorcyclist is the magnitude of the resultant friction force of the motorcycle wheels with the road (fk) with the projection of the total force of the rider and motorcycle against the slope of the road (W Sin θ). Students have not been able to explain that motorcyclists can use the motorcycle brakes to control the magnitude of the friction force (fk) = (W Sin θ). As long as (fk) = (W Sin θ) then the resultant force between fk = W Sin θ is zero. When the resultant force is zero, the motorcyclist will move at a constant speed or zero acceleration. What makes the rider able to glide with zero acceleration is the inertia of the rider and the motorcycle he uses across a downhill road. As a result of the still low understanding of the concept of students about the meaning of the First Law and its application in everyday life, and the very few examples or practicums of the application of the First Law on an inclined plane, while the examples of cases that are widely discussed on inclined planes are related to Newton's Second Law or uniformly accelerated straight motion, so that students have misconceptions, they conclude that the acceleration of an object on an inclined plane or crossing a downhill road cannot be zero because the object moves in a straight line and changes uniformly. The misconception that occurs among students regarding Newton's First Law is that if a child runs at high speed and suddenly stops, the child's body will stand up straight.

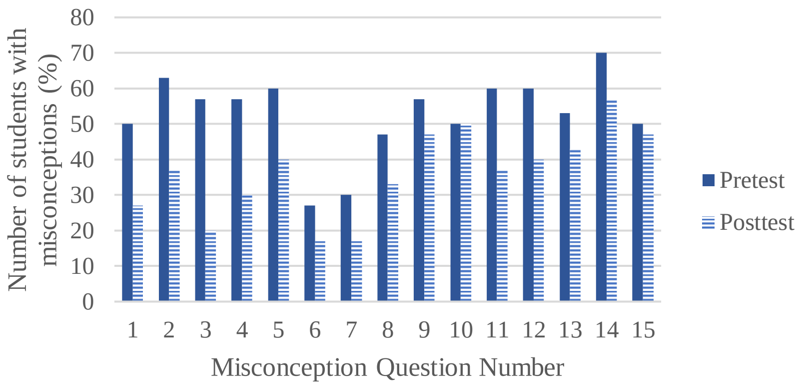

Figure 1. Percentage of Student Misconceptions for Each Question Item

Question number 14 has the highest percentage of misconceptions, which is 70%. This question is related to the analysis of the application of Newton's third law concept in everyday life in the event of a collision between two vehicles with different masses. They concluded that when there is a collision between two objects with different masses (for example between a car and a motorcycle) the force received by the motorcycle is greater than the force received by the car, this is proven by the damage to the motorcycle being more than the car. The discovery directly in the field of the difference in damage between the two vehicles as evidence of a collision, triggered the development of their conceptual understanding to be greater towards misconceptions. Furthermore, changes in student misconceptions after post-learning using the Investigation-Based Group Inquiry model worksheet are shown in Figure 2. The level of student misconceptions before learning was 53% and after learning it became 36%. The difference in the level of misconceptions before and after learning illustrates a decrease in the level of misconceptions by 17%. [1] Five main factors as causes of misconceptions, including: teachers, textbooks, teacher teaching methods, context, and students. There are five causes of physics misconceptions, namely students, teachers, teaching materials or literature, context and teaching methods [10].

In this study, efforts to reduce student misconceptions involved using investigation-based group inquiry model worksheets. These worksheets include theoretical summaries, sample questions, and investigation activities organized into six learning phases: orientation to factual phenomena or situations, hypothesis-driven planning for solutions, data collection and verification, experimental justification, analytical consideration, and verification and analysis of the process and outcomes. The experimental phase is a key strength, as it allows students to explore, verify, or test the validity of concepts in practical terms. This approach aims to enhance understanding of the material, boost creativity, and improve students' scientific process skills.[13–16]. The process of observing, making hypotheses, predicting, investigating, drawing conclusions and communicating are considered appropriate science process skills to be practiced in the early years of college [17].

Figure 2. Percentage of Students' Physics Misconceptions

4 Conclusion

The implementation of inquiry worksheets, group investigation-based investigations have succeeded in reducing the level of student misconceptions in the material of Newton's laws of motion by 17%, namely from 53% to 36%. The results of the study also found that some students still maintain their misconceptions even though efforts have been made to improve learning. In general, the inconsistency of students' initial conceptions with scientific conceptions is caused by students building their knowledge based on common sense alone, not based on scientific methods. Student knowledge is spontaneous knowledge without deeper reflection. Students will have different understandings of knowledge depending on their experiences and the perspectives used in interpreting it. Students' conceptions are often incompatible with scientific conceptions, however, if teachers do not pay attention to students' initial conceptions, it will result in subsequent learning difficulties [18]. Student misconceptions that remain unchanged after learning include: that there is no force acting on a stationary object. when a collision between two objects of different masses (a collision between a car and a motorcycle) the force received by the motorcycle is greater than the force received by the car, this is evident from the damage to the motorcycle being greater than to the car.

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