Identification of student difficulties in understanding kinematics: focus of study on the topic of acceleration

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Abstract. To design a quality lecture is necessary to identify the difficulties in understanding the concepts experienced by students. This research was a survey study that aims to identify the difficulties experienced by students in understanding the concept of kinematics, which is focused on the topic of acceleration. Seven reasoned multiple-choice questions were given to 159 physics and physics education students at the State University of Malang to archive this goal. The questions used in this study are presented in various representations, namely mathematical, verbal, pictures, and graphics. Based on the result of the analysis, the average percentage of students who answered correctly was 30.47. It can be concluded that students who understand the concept of kinematics are still low. This research shows that students still have difficulty understanding the concept of acceleration if the questions are presented in various representations.

1. Introduction

One of the important goals of learning physics is to achieve the correct understanding of concepts so that these concepts can be used to solve problems [1–4]. Students have an important role in understanding the concept of physics [5]. However, students often experience difficulties when constructing concepts because of preconceptions. This preconception is a misconception obtained from observing everyday events. This wrong concept has been 'attached' so that it is difficult to change into a correct concept. [6]. One of the fundamental topics that are difficult for students is kinematics [7–10].

Kinematics is the study of the motion of objects without considering the causes of motion. Students need to have a deep understanding of kinematic concepts such as position, velocity, and acceleration; both qualitatively-conceptually and quantitatively-operationally. Acceleration is an important topic because it relates to other topics in Physics, an example is particle dynamics [11]. However, the topic of acceleration is still often considered difficult by students.

To understand the concept well, students need to understand the key ideas of the concept. Key ideas in physics can be informed in a variety of representations. Students who understand the concept well will be able to explain the concept in various representations [12,13]. Multi representation is closely related to students' problem solving abilities [14]. There have been many studies that reveal the difficulties of students in understanding the concept of kinematics, but this research we focus on the topic of acceleration with the problems presented in various representations. Analysis of students' difficulties in understanding physics topics is still important. In research development, the focus of
This research is more specific on certain topics but more in depth. As we did, namely analyzing student difficulties in solving acceleration problems on various representations.

2. Methods

This research is quantitative descriptive. Data were collected using a survey method. The purpose of this study was to identify the difficulties experienced by students on the topic of kinematics with a focus on the topic of acceleration. The survey was conducted on students of physics and physics education with a total at 159 students at the State University of Malang in 2020.

Students' difficulties in understanding acceleration are expressed by using questions that are displayed in various representations. The representations that appear include mathematical, verbal, picture, and graphics. There are 7 questions used in this study. The questions consist of 1 mathematical problem, 2 graphic questions, 1 verbal question, and 3 picture questions (see Table 1). In this study, questions were presented using the online Quizziz platform. The data analysis technique used quantitative descriptive.

| Question Number | Assessed Abilities | Representations          |
|-----------------|--------------------|--------------------------|
| 1               | \( x(t) \rightarrow \) describes the acceleration of a particle as it moves | Mathematical to verbal |
| 2,7             | \( x(t) \rightarrow \) specifies the graph of a \( t \) in a specified time interval | Mathematical to graphics |
| 3               | Determines the relationship between the direction of velocity and the direction of the object's acceleration | Verbal to verbal |
| 4,5,6           | The object moves in a circle \( \rightarrow \) choose the direction of acceleration of the pendulum at a certain position | Picture to picture |

Data analysis was performed by determining descriptive statistics, namely measures of central tendency (mean, median, and mode) and size of data distribution (minimal and maximal score, and standard deviation). Then the student answer data is presented in the form of tables and bar charts to describe students' abilities in understanding the topic of acceleration.

3. Results and Discussion

In general, the data on students' abilities in understanding the topic of acceleration can be seen based on the score statistical data obtained. Descriptive statistical data on the score of understanding the concept of kinematics as shown in Table 2.

| Descriptive Statistical Data | Min | Max | Mean | Median | Mode | Standard Deviation |
|-----------------------------|-----|-----|------|--------|------|-------------------|
|                             | 0   | 100 | 30.47| 28.57  | 14.28| 20.66             |

Based on Table 2, the mean score of students' concepts understanding only reaches 30.47. This value shows that students' conceptual understanding is still low. Students still experience many difficulties in solving simple problems in kinematics. Only 2 (1.26%) students got a score of 100 and there were 14 (8.81%) students who got a score of 0. For more information, the percentage of students who got the correct answer is as shown in Figure 1.
Based on Figure 1, the easiest question because many students answered correctly is number 2. In question number 2, students are asked to determine the graph $a(t)$ based on the information $x(t)$. The problem is as shown in Figure 2.

An object is moving in a straight path with the equation for position as a function of time, which is as follows.

$$x(t) = -2 - 3t + 0.5t^2.$$  

With $x$ in meters and $t$ in seconds. Sign ($+$) is agreed as vector direction to the right and sign ($-$) as vector direction to the left. The graph of $a(t)$ over a time interval of $0 \, s \leq t \leq 10 \, s$ is…

In this question, students are assessed to understand the meaning of positive acceleration and negative acceleration. In this case, in an interval of $0 \, s \leq t \leq 3 \, s$ the object is moving to the left while slowing down. In the time interval $t > 3 \, s$ the object moves to the right as it accelerates. However, the vector of the object's motion acceleration is always constant - $1 \, m/s^2$ so the correct answer is option (A). However, many students think that $a$ (+) is acceleration and $a$ (-) is deceleration. So that students who have that understanding will choose option (B). There are 73 (45.92%) students choosing option (B). This shows that students do not understand well the meaning of (+) and (-) in the acceleration vector [7].

These findings need to be considered in designing classroom learning. The teacher must deepen students' understanding in interpreting the signs of acceleration. Teachers must be able to provide
deepening of concepts to students. Deepening this concept can be done by providing practice questions accompanied by feedback. Because no matter how many practice questions can strengthen the concept of students [15], therefore feedback is needed. In addition, it is necessary to give emphasis in teaching the concept of acceleration. Based on their experiences while giving lectures, students are often confused in describing $a(t)$ in graphical format. Therefore, the student's ability to represent the acceleration in a graph also needs attention.

Problem number 3 is the most difficult question. Only 22.64% of students can answer the questions correctly. Problem is a question that is presented in a verbal representation. The problem is as shown in Figure 3.

| An object is moving in a circle with a constant increasing speed. If the radius of the object's path is constant, then the relationship between the direction of velocity and the direction of the object's acceleration is…. |
|---|
| (A) Speed and acceleration are always parallel and in the same direction $(N = 44; 27.67\%)$ |
| (B) Speed and acceleration are always perpendicular $(N = 67; 42.14\%)$ |
| (C) Speed and acceleration always form an acute angle $(\theta < 90^\circ)^*$ $(N = 36; 22.64\%)$ |
| (D) Speed and acceleration always form an obtuse angle $(\theta > 90^\circ)$ $(N = 12; 7.55\%)$ |

**Figure. 2.** Question Number 3

Problem number 3 assesses the student's ability to understand that acceleration can be described as acceleration parallel to velocity and acceleration perpendicular to velocity. Based on Figure 3, it appears that students still do not understand acceleration well. A total of 44 (27.67%) students chose option (A). This shows that the student does not understand the function of acceleration perpendicular to velocity, namely to 'deflect' the direction of motion of an object. Even though the problem is given the condition that the object moves in a circular path. In addition, students often think that 'acceleration and velocity are always in the same direction' [16]. Regardless of the direction of the object's motion, at that time the acceleration has the same direction as the direction of the object's motion.

A total of 67 (42.14%) students chose option (B). This shows that students only understand centripetal acceleration. Often students think that in a circular motion the acceleration that occurs is only centripetal acceleration. This means that students do not understand well that the acceleration perpendicular to the velocity does not change the object's speed. The concept of accelerating objects in a circular trajectory tends to be difficult for students to understand, even many students experience misconceptions [17]. These findings imply the importance of designing good learning in teaching the concept of acceleration. Especially in teaching acceleration parallel to velocity and acceleration perpendicular to velocity. It should be noted that the ability of students to determine vector components is often an obstacle. This is indicated from 12 (7.55%) students who chose option (D). If the acceleration forms an angle greater than 90°, the component of the acceleration perpendicular to the velocity will cause the object to slow down. However, it seems that this is not well understood by students. Or it could be that they have difficulty determining the components of the acceleration vector. Therefore, in the learning process, when teaching the topic of kinematics, it is necessary to ensure that students have good ability in understanding vectors.

4. Conclusion
The results showed that the students' ability to understand the topic of acceleration was still low. This is indicated by the average score of students' concepts understanding of 30.47. Students still have a lot of difficulty in constructing $a(t)$ graph based on the $x(t)$ function. In addition, students still experience many difficulties when interpreting acceleration perpendicular to velocity and acceleration parallel to velocity.
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