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Misconceptions about Acceleration among Prospective Physics Teacher: The Importance of Discussion of Acceleration as a Vector Quantity

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Abstract

Acceleration is a fundamental concept in mechanics. Understanding this concept influences understanding of other concepts in physics. The author's experience of teaching mechanics to prospective teacher students found that many students experienced misconceptions. Literature shows that the problem of misconceptions about acceleration is not unique to researchers. The researcher was curious about what caused this misconception. Researchers suspect that students' misconceptions about acceleration occur because the concept of acceleration is not fully understood as a vector quantity and understanding acceleration is independent of understanding the influence of force on acceleration. This research aims to describe the problem of misconceptions experienced by prospective physics teacher students regarding acceleration and its possible causes. Data was collected over four years, namely from 114 prospective physics teacher students in the first semester of the physics education study program until 2022.They were high school graduates majoring in science where physics, which includes mechanics, is one of the compulsory subjects. Data was collected through multiple choice tests and descriptions. The research results show that the misconceptions experienced by students are: 1) Acceleration is not fully understood as a vector quantity; 2) Students have difficulty explaining the relationship between acceleration and the force that causes it.

Keywords: Acceleration, Misconception, Vector,

1 Introduction

Acceleration is a fundamental concept in Physics. The concept of acceleration is identified as the basic building blocks of scientific theories that are highly successful in explaining and predicting observable phenomena. The ability to this concept correctly is an essential prerequisite for any scientific work. Even though it is important, the concept of acceleration is difficult for students to understand. Many first-year students have

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misconceptions about acceleration even though this concept has been studied in high school.

Allen [1] defined misconceptions as preconceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions, and factual misconceptions. Misconceptions occur when students consider physical phenomena using their minds and confidence of being able to explain them with the correct knowledge. Meanwhile, Kuzcmann formulated misconceptions as beliefs which contradict accepted scientific theories [2]. Kuczmann further explained that Misconceptions in physics give seemingly true explanations for correlations and phenomena, but they are not consistent with the experiment. They are based on superficial, commonplace considerations.

Suprapto [3] identified five types of misconceptions, namely: are five kinds of misconceptions, namely: (a) preconceived notions; (b) non-scientific beliefs; (c) conceptual misunderstandings; (d)misconceptions of local languages (vernacular misconceptions); and (e) factual misconceptions. The source of misconception could be the result of teaching materials, daily experience or teaching and learning process [4].

The problem of misconceptions about acceleration is not unique to researchers but is also found in various places. Number of studies show that this concept is difficult for students to understand, and many students understand it incorrectly or even have misconceptions [5-8].

This research aims to uncover the problem of misconceptions about acceleration faced by prospective physics teacher students who are in their first semester at Sanata Dharma University, as well as the possible causes. The results of this research are useful for reducing the level of misconceptions about acceleration which can be applied not only to physics learning at the university level but also at the high school level.

2 Material and Methods

The respondents of this research were 114 people consisting of four generations of students. Participants in the research were all students who took Kinematics courses in

2019, 2020, 2021 and 2022. The number of students taking Kinematics courses in four years is presented in Table 1.

Data was collected using multiple choice tests and essay questions. Data were analyzed descriptively. Based on experience teaching mechanics, researchers suspect that the misconceptions about acceleration experienced by students are related to students' understanding of acceleration as a vector. Based on this suspicion, the researcher designed questions specifically intended to reveal it. Data was collected through closed-answer questions and descriptive questions. In descriptive questions, students are given the freedom to express their opinions regarding a particular concept.

3 Results and Discussions

Question A.

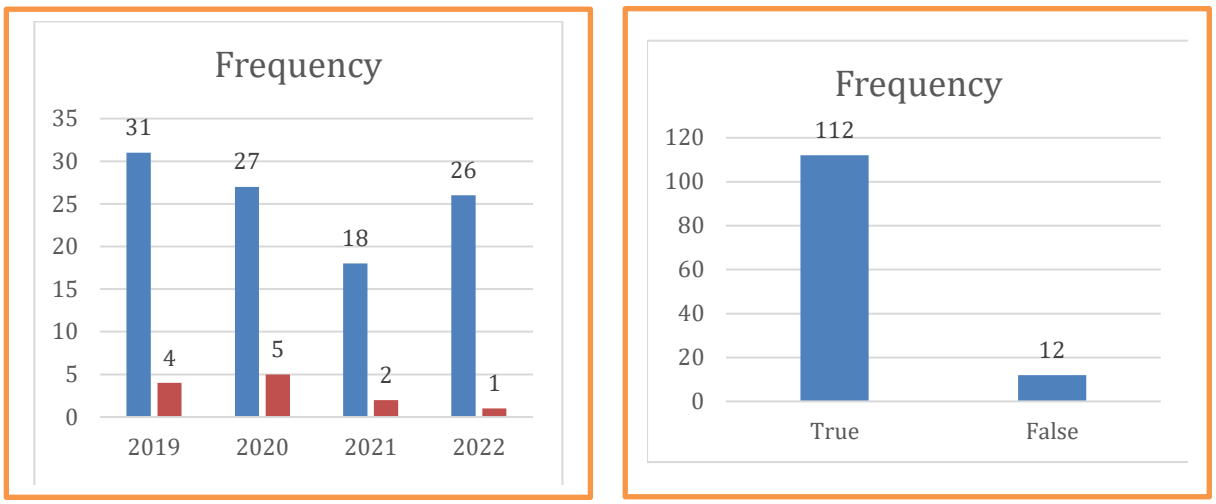
If the acceleration of an object is negative, then the object's motion is slowed down, and if the acceleration is positive then the object's motion is accelerated. True/False.

This statement is wrong because negative or positive indicates direction, while accelerated or slowed down is the value of acceleration. If the object is moving to the left and the acceleration is also to the left, the object will speed up or accelerate.

Student answers are presented in Fig. 1a is the student answer per student year group and Fig. 1b is the total answer from the four groups. The students' answer to question A revealed that 89.47% of students believed that if the object's acceleration was negative then the object's motion was slowed down and if the object's acceleration was positive then the object's motion was accelerated.

Table 1. Participants of the research.

Year	Number of students
2029	35
2020	32
2021	20
2022	27
Total	114



(a) (b)

Figure 1. Students' answer to Question A: (a) per year group students; b (total).

The students' beliefs were confirmed through their answers when they agreed to the statement that the acceleration of an object thrown vertically upwards is negative and the acceleration of an object experiencing free fall is positive.

Difficulty understanding the positive sign (+) and negative sign (-) in acceleration was also revealed in research conducted by Shodiqin and Taqwa [9] with student respondents who were prospective physics teachers. Students' understanding that when an object's acceleration is negative, the object experiences deceleration shows that students' understanding is influenced by intuitive understanding in everyday life regarding acceleration and deceleration [10-11].

Students understand that acceleration is a change in speed per unit of time. In everyday life, positive changes have the meaning of increase and negative changes have the meaning of reduction. Using this intuitive understanding, positive acceleration is interpreted as an increase in speed or acceleration and negative acceleration is interpreted as a reduction in speed or deceleration. This is confirmed through the following statement from one of the students:

"... positive acceleration means the change is positive, yes it means the speed gets bigger and bigger... the object's motion accelerates, and if the acceleration is negative, it means the speed decreases.... Mmm things are getting slower." (student 1)

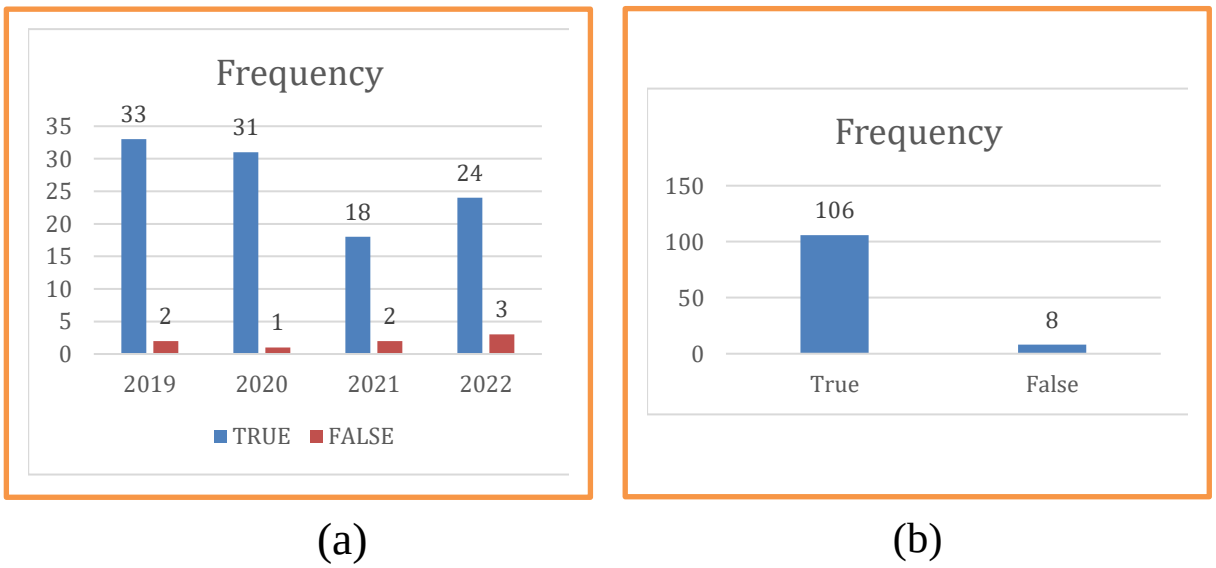
Providing this explanation, students do not consider that acceleration is a vector quantity. This shows that students do not fully understand that the concept of acceleration involves physical concepts and vectors to represent it. Such difficulties were also found in research conducted by Pedrill [12].

Question B.

This question was intended to confirm the answer to question A. In everyday life, it is known that if an object is thrown vertically upwards, the object will slow down and then fall again. When it falls, the object's motion gets faster and faster. Students are given the following statement. Students are asked to assess whether the statement is true or false.

A ball is thrown vertically upwards and then falls back down. When it is moving up, the ball experiences negative acceleration and when it goes down the ball experiences positive acceleration.

This statement is wrong. Whether the object is moving up or down, the object's acceleration remains negative, the direction is downwards. The acceleration experienced by an object is the gravitational acceleration that arises because of the Earth's gravitational force, the direction of gravitational force is always towards the center of the Earth. Student answers are presented in Figs.F 2a and 2b, 2a is the student answer per student year group and 2b is the total answer from the four groups.



(a) (b)

Figure 2. Students' answer to Question B: (a) per year group students; b (total)

The student's answer to question B confirms the student's intuitive understanding. When an object is thrown upwards, the object's motion slows down, students understand that the object's acceleration is negative. On the other hand, when an object is falling, the object accelerates, students understand that the object's acceleration is positive.

Based on students' answers to questions A and question B, it seems quite convincing to state that students' understanding of acceleration is greatly influenced by the intuitive understanding in everyday life that positive has the meaning of increasing and negative has the meaning of decreasing. By using this understanding, students understand that positive acceleration causes objects to speed up and negative acceleration causes objects to slow down.

Question C.

Through questions A and B, it was revealed that students had misconceptions about acceleration. Students cannot understand acceleration as a vector quantity where the positive and negative signs are not related to accelerated or slowed motion. Understanding accelerated or slowed motion requires simultaneously paying attention to the direction of motion and the direction of acceleration.

Next, the researcher asked questions accompanied by pictures to help students understand the problem visually. Given an object is moving to the left and the object experiences acceleration in the direction to the left. Students are given several statements that must be judged as true or false. The statements that must be judged true or false are: 1. The speed of the object is negative; 2. The acceleration of the object is negative; and 3. The movement of objects gets faster and faster. The answers to these statements are: 1. Correct, the speed of the object is negative; 2. Correct, the acceleration of the object is negative; and 3. True, the movement of objects gets faster and faster.

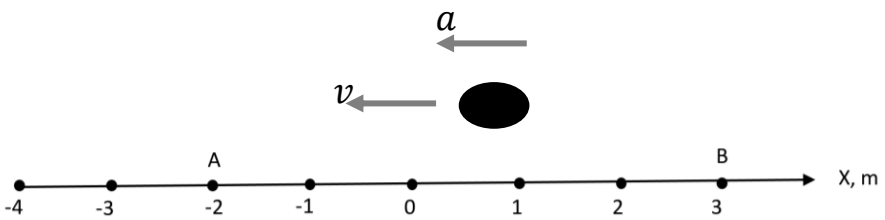


Figure 3. Object moving across horizontal line.

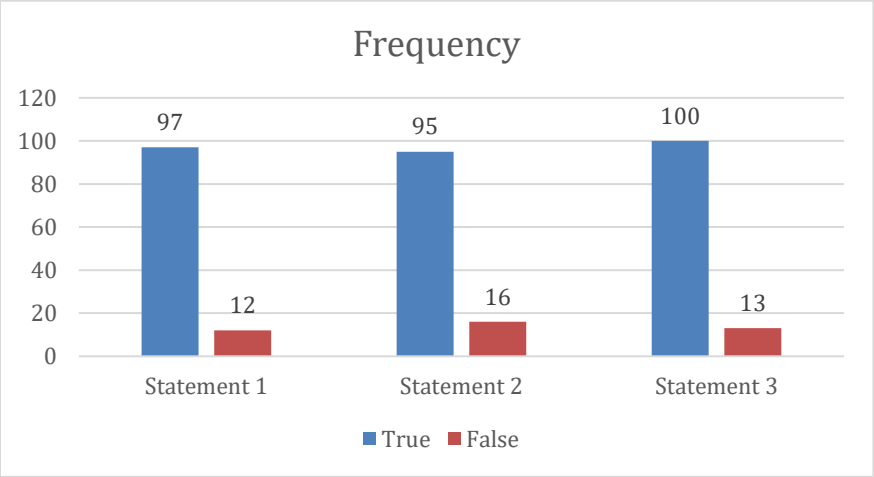


Figure 4. Students' answer to question C.

Students' answer to question C reveal something different from the answer to Question A and B. The student's answer to question C shows that the student understands that speed and acceleration are quantities that have value and direction, namely vector quantities, as expressed by student 5.

"If you are moving to the left and experiencing acceleration to the left then the object is getting faster, because the object seems to be being pushed, conversely if the object is moving to the left but the acceleration is to the right... the object seems to be held... the object is slowed down."

Based on students' answers to question C, it can be concluded that when students are reminded about the direction of speed and acceleration, students can provide correct answers and explanations.

This fact strengthens the researchers' suspicion that students' misconceptions occur because the discussion they receive in secondary school does not emphasize discussion of speed and acceleration as vector quantities. Apart from that, the physics textbooks they use may also contain misconceptions as stated in one of the following books published by the Ministry of Education and Culture [13]. On page 26 of the book, it is explained that the equation of motion for an object thrown vertically upwards is:

$$v_t = v_0 - g.t$$
$$h = v_0.t - \frac{1}{2}gt^2$$
$${v_t}^2 = {v_0}^2 - 2\,gh$$

$v = velocity; h: height; g: gravitational\ acceleration, t: time;$
$v_0: Initial\ velocity;\ v_t: velocity\ on\ t$

Figure 5. Equation for vertical moving object in high school physics textbook.

Meanwhile, the equation of motion for an object in free fall, namely when the object experiences no force other than the force of gravity, is stated on page 29 as seen in Fig. 6.

Based on the explanation in the high school physics textbook as described above, it can be assumed that the misconceptions held by students originate from studying physics in high school. Considering that the book was published by the Ministry of Education and Culture, it can be assumed that the book is used in various regions of Indonesia. Hopefully this explains why some students who have just graduated from high school have the misconceptions as described above.

Question D.

This question was intended to reveal the extent to which students understood the concept of acceleration which was studied in the discussion about rectilinear motion and acceleration because of force.

$$v_t = v_0 + g.t$$
$$h = v_0.t + \tfrac{1}{2}\, gt^2$$
$$v_t^2 = v_0^2 + 2\,gh$$

Figure 6. Equation for free fall object in high school physics textbook.

The question or in fact the assignment was given to the students draw an object that was thrown vertically upwards and then the object came back down. Students were asked to describe the motion of objects along with the velocity vector, acceleration vector and gravitational force vector as shown in Fig. 7.

When trying to draw, almost none of the students drew correctly on the first drawing they made. Some are not even able to represent the velocity vector, acceleration vector and force vector correctly. After going through discussions and explanations, finally several students were able to draw correctly. The following are two examples of drawings made by students.

This phenomenon provides information to researchers that students have not been able to relate their understanding of the three concepts of speed, acceleration, and force as a whole in one single event. Based on the data revealed from this research, the author suspects that the stages of discussing rectilinear motion and Newton's laws of motion in secondary schools play a role in the emergence of student misconceptions. In high school physics lessons, discussions of rectilinear motion are not linked to discussions of force.

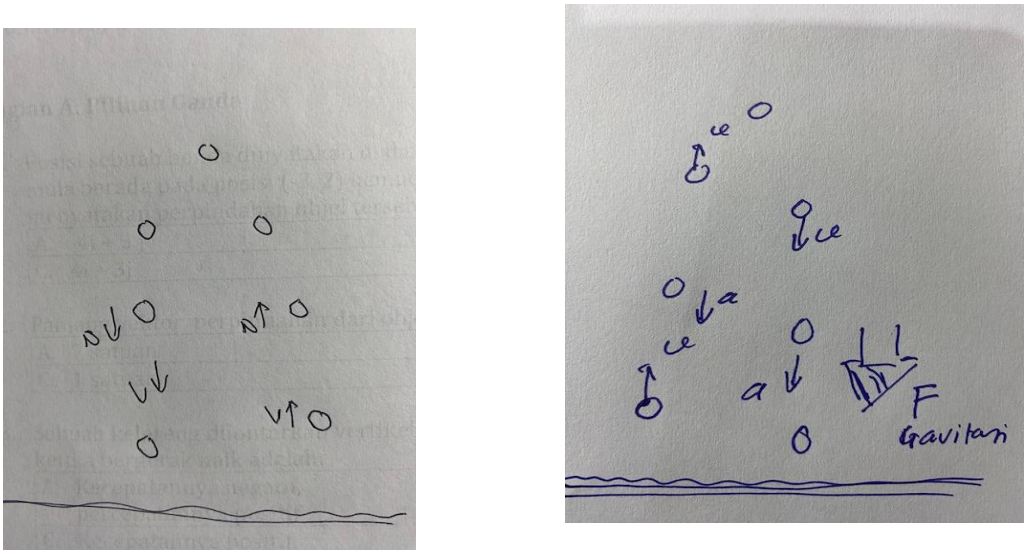


Figure 7. Students' illustration about vertical moving object with velocity, acceleration, and force vectors.

The answers that reveal students' misconceptions about acceleration show that acceleration is indeed a complex concept. This concept, as mentioned in the literature mentioned above, involves aspects of mathematics, vectors and physics. Judging from its relationship to other concepts in physics, the concept of acceleration is directly related to the concept of motion and the concept of force.

Fig. 8 shows the relationship between the concept of acceleration in rectilinear motion and the concept of acceleration because of force. In the context of motion, the concept of acceleration is discussed after first discussing the concepts of position, displacement, and speed. To provide a correct understanding of the concept of acceleration, then since the discussion regarding position and displacement it must be consistently discussed that position and displacement are vector quantities. Likewise, when discussing speed, speed must be discussed consistently as a vector quantity. With the consistency of position, displacement and speed discussed as vector quantities, acceleration is also discussed as a vector quantity.

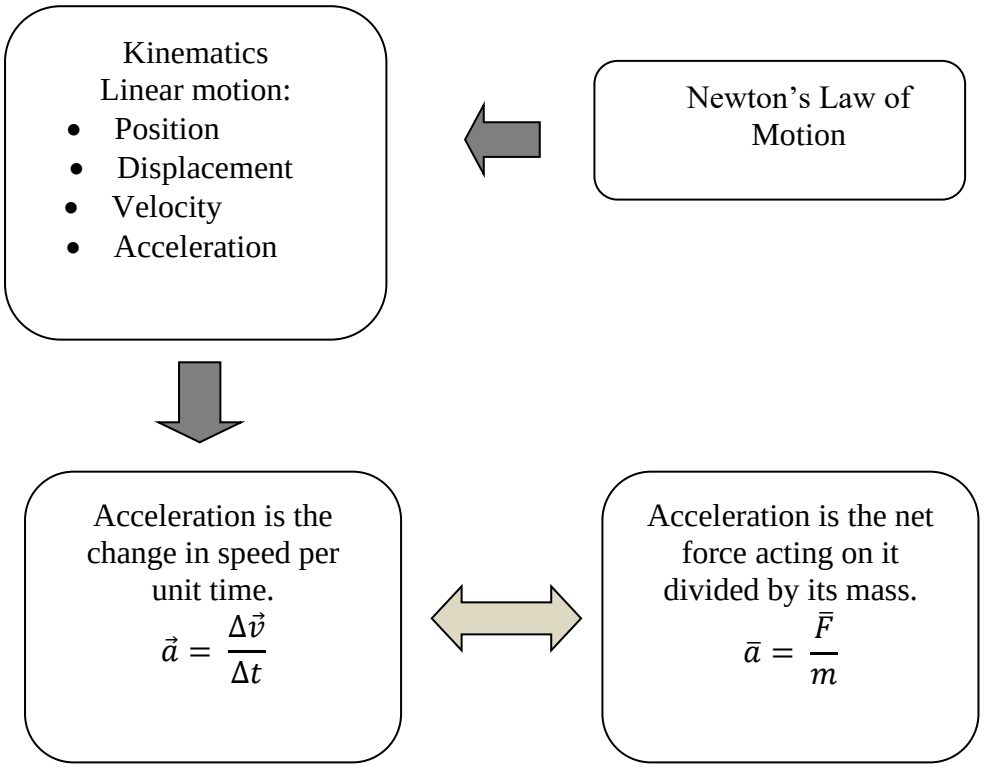


Figure 8. Relationship between concept of acceleration in Linear motion and Force

The second thing that can be learned from Fig. 8 is acceleration as a result of a force. By looking at diagram in Fig. 8 it seems clear that the discussion regarding acceleration should be carried out in its entirety, both acceleration as an entity in the movement and acceleration as a result of force. Teachers need to help students understand the concept of acceleration as a movement entity and because of a force as a whole and not fragmented.

Learning from the diagram above, it is hoped that when teaching about acceleration, teachers not only discuss acceleration as a change in speed in the context of straight motion but also need to discuss acceleration because of a force whose value is influenced by the magnitude of the force and the mass of the object and whose direction is the same as the direction.

4 Conclusions

Students' misconceptions about acceleration are influenced by intuitive knowledge from everyday life which is not in line with the laws of physics. From this research it is also revealed that misconceptions about acceleration arise due to a lack of attention to acceleration as a vector quantity. Other information revealed from this research is that students' understanding of acceleration is not fully integrated with their understanding of the causes of acceleration. Based on the findings above, researchers recommend that learning about rectilinear motion be consistently discussed using vector quantities to avoid misconceptions. Second, the discussion about acceleration is discussed in its entirety, including force as the cause of acceleration.

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