

Activities to enhance students' understanding of acceleration

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Abstract. According to literature, the most important factor in education is to determine what students already know and to consider when teaching them. Unfortunately, there is a body of knowledge from physics education research revealing that we cannot simply build onto all existing knowledge that students have, because they contain misconceptions that differ from the accepted scientific understanding. As an example, students understand acceleration as an increase in the magnitude of speed or velocity. Based on that understanding, a brake pedal and a steering wheel of a motor car are not regarded as accelerators because they don't increase the magnitude of speed. That is caused by the everyday usage of the term which differs with a scientific understanding. Other examples in mechanics where students have lack of understanding is their understanding of the concept of force. Literature revealed that students believe that a constant force causes an object to move with a constant speed, some force always acts in the direction of motion and that a larger mass falls faster towards the earth than a small mass. Some physics education researchers argue that productive elements in learners' existing knowledge should be determined and used as bases for building scientific knowledge. Despite an earlier teaching of the concepts of motion in relation to acceleration from high school and in their first-year of physics at university, many of the students have difficulties in the problem solving required for the acceleration assessments. It is against this background that this paper presents and evaluates the impact of the activities that were designed to enhance students' understanding of the concept of acceleration. The evaluation of the impact of intervention was done through Google forms. Preliminary analysis of the results reveals that if the vector nature of acceleration is emphasized, students would also value the importance of including the change in direction as the result of acceleration. The results implied that teaching mechanics should start with the impact of force in our everyday life since acceleration is the visible impact of force.

1. Introduction and Background

The Physics Education group at the University of Johannesburg, Physics department has engaged in the study of the ways in which students in the physics preservice teacher module activities can enhance their understanding of acceleration. The degree of difficulty of the module is relevant for the student teachers. This paper, devoted to the mechanics' concepts, reports on the ability of students to apply the knowledge of the concept "acceleration" in interpreting motion in real life.

Since acceleration is the results of the net force, difficulties related with force on motion have been previously studied, for example, for diagnosis and assessment purposes, standards comprehensive test have been developed [1, 2, 3] to probe students 'ideas about forces and related concepts. However, [4] highlighted students' alternative ideas about force and motion as follows:

- if there is motion, then a force must be acting;
- if there is no motion, then there is no force acting;
- without motion, one cannot talk about force;

- when a body moves, there must be a force in the direction of motion;
- a moving body will stop, when its force is exhausted;
- there exists a force in moving bodies that maintain motion;
- motion is proportional to acting force; a constant.

It is interesting to note that these novice ideas, often referred to as alternatives conceptions or misconceptions, are very similar to the historical ones [5, 6, 7] and at all levels they cause a learning difficulty for learners and are reported to be persistent to change even after instruction.

The study of forces continues to situation where there are cancellations of all forces. According to Newton's first law, if the body is not at rest, it thus remains in uniform rectilinear motion and it seems this law contradicts everyday experience, a driver needs to pedal to keep going, and a car comes to rest unless the engine continues to provide energy.

The teaching of the laws of motion can be approached by focusing on acceleration, which is related to force through Newton's second law. From the physics understanding, acceleration is more fundamental than velocity; it is absolute, whereas velocity is relative and depends on the frame of reference chosen [8]. Acceleration, unlike velocity, can be measured within the moving system. It can be detected by the body in motion and the body can be that of the student. This makes it possible to enhance on, rather than reject, the experience by the student and start in situations which where everyday observations do not contradict Newtonian concepts. The concept of vectors must be understood prior to introducing the acceleration. Thus, the vector nature of acceleration will not be abstract concept but will be more evident in the daily three-dimensional motions.

Acceleration in mechanics is portrayed together with common misconception about the force and motion. In many introductory physics textbooks, acceleration is introduced mathematically, or something derived from measurements or something theoretical and less is said about its definition in real life. For example, acceleration is closely linked to force through Newton's second law ($a = F/m$), but, in contrast to the understanding of force, seems to have received very little attention by Physics Education Research [9]. Acceleration as the time derivative of velocity or "rate of change can be obtained from a measurement of velocity or distance relative to another object. For motion in a circle with constant angular velocity, the acceleration is always pointing to the center and the resultant force, obtained by combining the force from the rider with the gravitational force, mg , should then always be directed/pointed toward the center. The magnitude of the centripetal acceleration does not change. In order for the rider to experience weightlessness at the top, the centripetal force must have a magnitude mg . The task related to the acceleration has been found to expose an incomplete understanding of forces, velocity and acceleration. One aspect that is found to be problematic is that the acceleration from other students is not a vector.

In order to raise the level of our students understanding of task related to acceleration, the present study aims to determine how students respond to questions about real life application of acceleration. Motivation for this work arises from experiences with first-year student teachers at the University of Johannesburg (UJ). Despite an earlier teaching of the concepts of motion in relation to acceleration from high school and in their first-year of physics at university, many of the students have difficulties in the problem solving required for the acceleration assessments. Different approaches have been used to probe deeper into the nature of the difficulties. In this study, activities to enhance students' understanding of acceleration are presented based on Newton's first and second law.

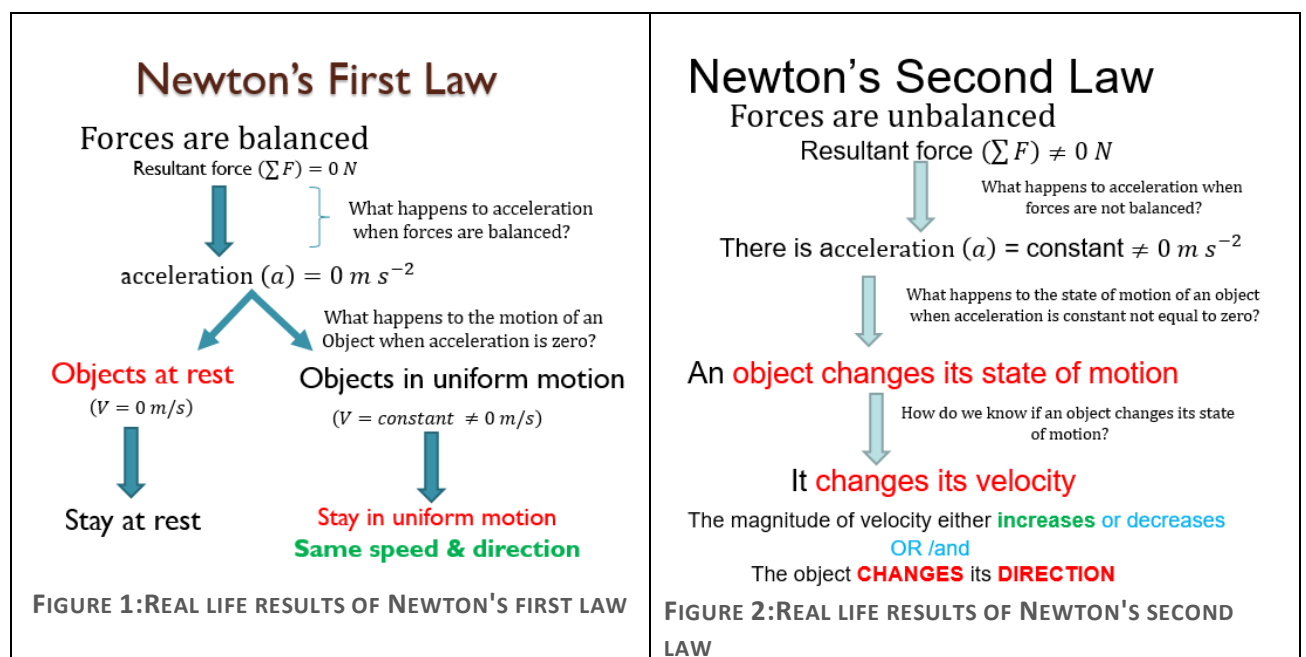
2. Methodology

2.1 Participants in the study

The present study involved students who were enrolled in courses for semester 1 of Bachelor of Education (B.Ed.) of their first-year physics at University of Johannesburg (UJ). Out of the 40 students 24 were male and 16 were females. Only 35 of the students were present in class on the day of the test. Most of these students graduated from high school the previous year and were taught physics at high school. This cohort of students was taught basic mechanics in the first semester of first-year physics. The Newton's laws were taught and explained in detail using different examples and exercises in the class that this study was done. Given that first-year students were taught the concepts of force and acceleration in their high school curriculum, care was taken in the use of the terminologies and formulae to enhance the understanding of the concept of acceleration. All participants in the study had either a smart phone or a computer that can be connected to university WI-FI system. These smart phones and/or computers are accepted as tools for learning in class, hence instructional activities included the use of them under specified conditions. The students were told about the nature of the study and were ensured that their information would be kept confidential.

2.2 Intervention activities

Figures 1 and 2 were taken from slides used to teach Newton's first and second law emphasizing the impact of acceleration on an observable motion. Through an interactive engagement student were asked questions based on figures 1 and 2, for example, "What happens to the motion of an object when acceleration is not zero?" We train our students to answer questions as follows: If acceleration is zero /non-zero then the motion of an object will remain constant /change. On figure 2 it was further emphasized that "even the change in direction when the magnitude of speed is constant is regarded as acceleration".



2.3 Instrument used for data collection

This was a once-off post-test design aimed at exploring students understanding of the concept of acceleration from their point of view after instruction. Four questions in the form of three tier questionnaires were developed by researchers taking into considerations, their experiences in teaching the concepts in high school, at tertiary level and knowledge derived from research in Physics Education Research (PER). The questionnaire was administered four weeks after the beginning of the first semester in class using Google form. Google form was opted because it allows an easy retrieval and analysis of answers given by students. The questionnaire was allocated 45 minutes to be completed and all students finished within the allocated time. As a norm, students were familiar with the aim for administering the questionnaire and their voluntary participation was explained prior to administration of Google forms in all activities. The questions were formulated to be answered as follows: In each question, except if asked to define, students were expected to give or justify with scientific reason or evidence.

3. Results and Discussion

The results are presented and discussed per question. The question whose results are presented and discussed will be shown first. Using phenomenography, students' understanding was concluded based on three criteria: correct options, correct explanation and 100% confident about the option chosen, explanation given.

Question 1: When an object moves with non-zero constant acceleration, its magnitude of velocity...

A: increases B: Decreases C: Remains constant D: Both A and B are correct. The correct answer is option D because when acceleration is non-zero constant, the magnitude of velocity changes. The results of students' options are shown in figure 3 that follows.

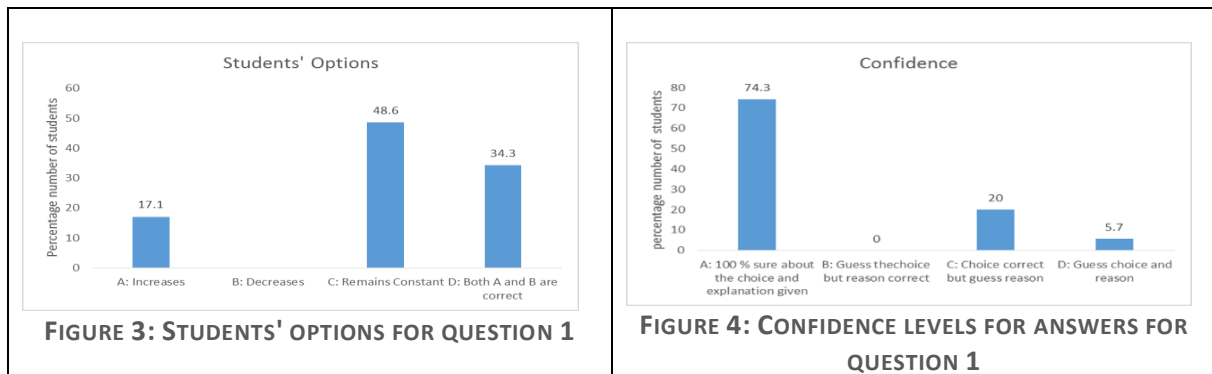
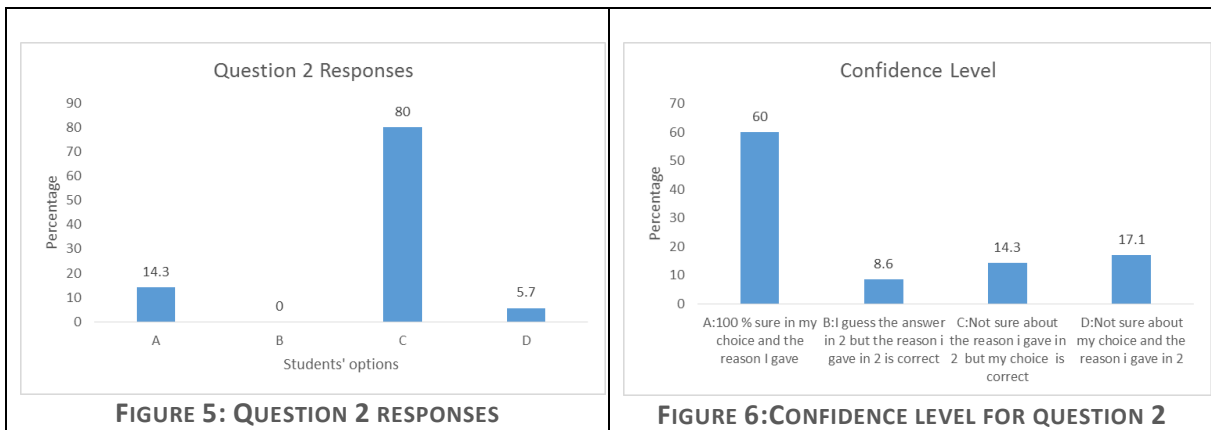


Figure 3 shows that 34.3 % of students chosen the correct answer, but further analysis of their explanations revealed that only 20 % gave the correct explanations which implies that 14.3 % guessed the answer. However, no students opted for decrease in magnitude of velocity and in figure 4 the majority of students were confident that their options were correct which shows that many students still held the misconception that acceleration is associated with only the increase in magnitude of velocity as reported in earlier section.

Question 2: Two cars are moving in the same direction (the positive direction) on a straight road. The acceleration of each car also points in the positive direction. Car 1 has a greater acceleration than car 2. Which one of the following statements is true?

- A: The velocity of car 1 is always greater than the velocity of car 2.
- B: The velocity of car 2 is always greater than the velocity of car 1.
- C: In the same time interval, the velocity of car 1 changes by a greater amount than the velocity of car 2 does.
- D: In the same time interval, the velocity of car 2 changes by a greater amount than the velocity of car 1 does.

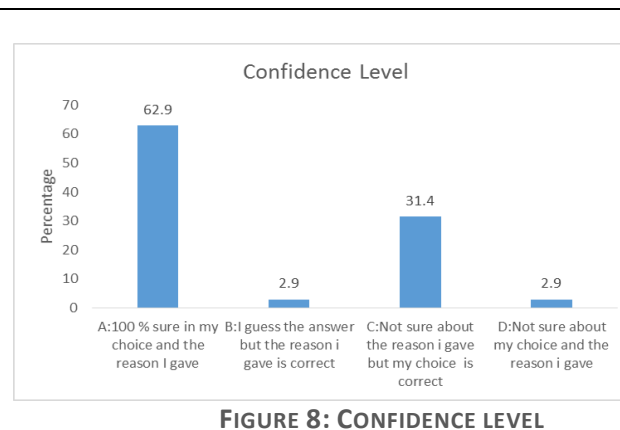
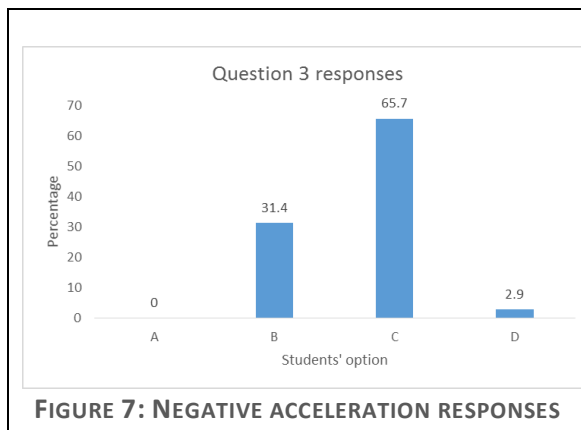
The results of question 2 are shown in figures 5 and 6. Figure 5 shows that 80% of students chose C which is the correct answer and 20% of students got it wrong. Analysis of their explanations revealed that 60% of them were confidence about their chosen answer. Based on this results, it can be claimed that only 60 % understood.



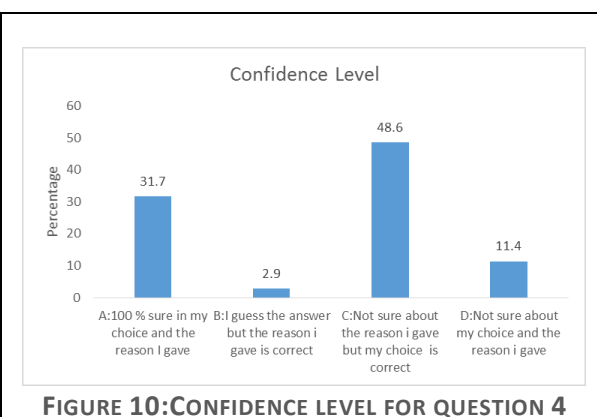
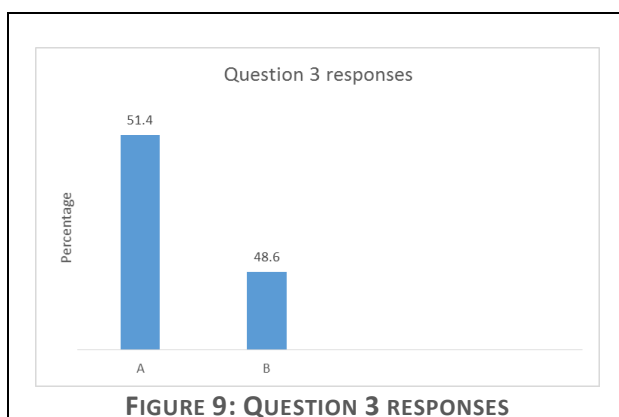
Question 3: If an object has a negative acceleration it means:

- A: It increases its velocity
- B: It decreases its velocity
- C: the acceleration is in the opposite chosen direction
- D: Others

The most appropriate answer is option C, so 65.7 % opted correctly as shown in figure 7, no one opted for option A which implies that students associate negative acceleration with the decrease in velocity. It was encouraging to see that 62.5 % were sure of their options and explanation they gave as indicated in figure 8.



Question 4: At one instant of time, a car and a truck are traveling side by side in adjacent lanes of a highway. The car has a greater magnitude of velocity than the truck has. Does the car necessarily have the greater acceleration? Options are: A: Yes B: No. In this question 51.4% said yes while 48.6% said no, the correct answer is no, bigger magnitude of velocity doesn't necessarily imply greater acceleration. Further analysis of their explanations and confidence level revealed that only 37.1 % have shown an understanding of the concept of acceleration.



4. Conclusion

Based on the answer's students gave, it can be concluded that pre-service students under study conceive acceleration as a mathematical concept that need to be memorised. Based on this finding, we suggest that the teaching of the concept of acceleration should start with the real life exposition of its impact followed by mathematical formalisation like equations. We recommend that more activities that challenge students to answer a key question: "What it means to accelerate?" should be developed before they are engaged with mathematics. Since there is less emphasis of change in direction during the mathematical application of the definition of acceleration, we further recommend that activities developed should put more emphasis on helping students to understand that the change in direction is also the result of acceleration. For example, in both figures 1 and 2, direction was emphasised as also key to determine if an object is accelerating. Through interactive engagement and using guiding questions on figures 1 and 2, some of the misconceptions like "greater magnitude of velocity means greater acceleration" were corrected. The results of this study based on the analysis of students' explanations for their choices concurred with literature that misconceptions can still be available after

instruction, however, based on the quality of the reasoning students gave, it can be claimed that the approach used had a positive impact on enhancing students' understanding of the concept of acceleration. This study added sample activities that can be used as a guide to develop interest in physics concept of acceleration by relating content with context where the concept is applied. The results cannot be generalised as the study was only conducted to limited number of students.

Acknowledgements

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