Students’ explanation of motion in real-life context

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Abstract. The concepts of force and acceleration are crucial when motion in both one and two dimensions is described. The relationship between the two concepts were explained in terms of Newton's first law and Newton’s second law of motion which is included in both the high school and university first year physics curriculum. It is expected that both high school and university first year Physics students can explain motion in real- life context in terms of terminologies used in Newton's first and Newton's second laws. The paper present students’ explanation of motion after viewing PheT simulations. Preliminary results revealed some discrepancy in students understanding of both Newton's first and Newton’s second law.

1. Introduction and background

Before Galileo and Newton, researchers thought objects slowed down or stop because they have the tendency to do so. They thought that, if you want the object to continue moving, the force must be applied on the object. They did not consider the effects of other forces (e.g., friction, gravity, and air resistance) here on Earth that cause objects to change their velocity. A considerable number of studies have been conducted within basic mechanics, and according to [1], conceptions of force constitute the dominant theme in the misconceptions’ literature. Among the widely-used instruments for probing the student’s conceptions about force is The Force Concept Inventory (FCI), see [2]. This instrument, with carefully constructed multiple-choice questions, has been used in schools and universities worldwide for many years, often to assess the achievements of teaching methods in mechanics. Results show that the Newtonian understanding of force remains a challenge for students across international contexts and levels of study [3-4]. Students’ are often found to reason their conceptual understanding as if they were not taught Newtonian mechanics. They associate force with movement, understand force as something an object carries and will be used up during movement, and anticipate that large objects are acting with small force than small objects in an interaction see [5] for an overview of student conceptions.

Many studies of misconceptions in mechanics and other areas suggest that they form part of students’ alternative frameworks, which needs to be challenged and replaced by more scientific ways of thinking. However, studies have argued, misconceptions are not necessarily held by students prior to teaching, but might just as well be because of the teaching process [6]. Therefore, PheT simulations presents the concepts of force and motion that are important to understand how simulation(s) may contribute to students’ inconsistent or flawed conceptions. The study was aimed at assessing how students explained real contexts in terms of Newton’s first and second law.

2. Methodology

The present study involved students who were enrolled in courses for first semester of Bachelor of Education (B.Ed.) and Bachelor of Science extended (BSc) of their first-year physics at University of Johannesburg (UJ). The first-year B.Ed. program consisted of 33 students and the BSc extended program constitute of 111 with 104 students present in the day of the data collection.

2.1. All students from both groups were taught basic mechanics in the first semester of first year physics. Data was collected from both groups through the google form.

2.2. Design

This was a once-off post-test design aimed at comparing the two groups of students taught using different methods by different lecturers. Their background in terms of the symbols or levels they obtained in grade 12 in selected subjects are shown in figure 1 below. Based on figure 1, there were no significant difference in terms of the levels obtained by both students in physical sciences, however 75.8% of B.Ed. students scored well (level 6) in English and only 39.4% of BSc students got level 5 in their grade 12 results. It should be indicated the only 51.6% (17 students) of B.Ed. program students scored above level 4 and 96.1% (100 students) of BSc extended program students scored above level 4 in grade 12 mathematics.

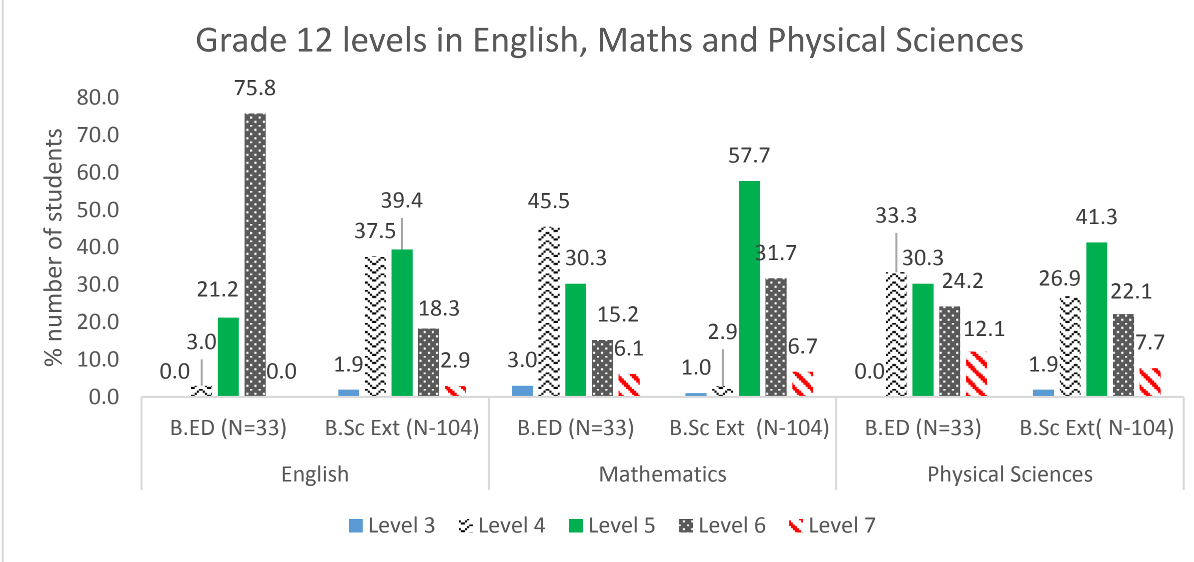

Figure 1. Student's grade 12 results in selected subjects.

2.2.1. The instrument used to collect data.

Four questions probing students' understanding of Newton's first and second law of motion were developed by authors with an aim to probe student's understanding of how they apply these two laws in real life context as demonstrated by a simulated picture shown in some of the figures below. To be specific, questions focused on the assessment of "constant force implies constant speed or velocity misconception", the impact of the equilibrant force on accelerated motion, the impact of added mass on motion in two dimensions and the impact of frictional surface on the motion of an object.

2.2.2. Procedure

The two Newton's laws were taught and explained in detail using different examples and exercises in the respective classes that the 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, and PheT simulation (which can be freely accessed or downloaded at the following link: https://phet.colorado.edu/en/simulation/forces-and-motion-basics) was used to explain the concepts of the force and acceleration.

The data was collected from two different first-year classes: first-year preservice teacher's class and four-year first-year students (physics first-year extended BSc students). This data was collected using the google forms in the form of questionnaires. The questions were formulated to be answered as follows correct choice, stating the law and then use the law to justify their answers. Both classes were given the questionnaires in class to answer in a period of 45 minutes. The first-year teachers class consisted of 33 students and all responded to the questionnaires and the extended students constitute of 111 with 104 students present in the day of the data collection.

3. Results and Discussion

The results are presented and discussed in percentages in different histograms and the actual numbers of participants in brackets. Care has been taken in explaining result from the histogram and actual number of students in each category to the importance of the discussion of the results.

3.1 Constant force implies constant speed or velocity misconception.

This question was aimed at assessing students if they still hold the misconception that "constant force implies constant speed or velocity". It was framed as follows: *A person pulls a stationary cart on a frictionless surface with a constant force of magnitude 50 N to the left as shown on the diagram. What do you think will happen to the motion of the cart while being pulled with a constant force of 50 N?* The percentage results of students' options are shown in figure 3.

Figure 2. Simulated diagram for question 1.

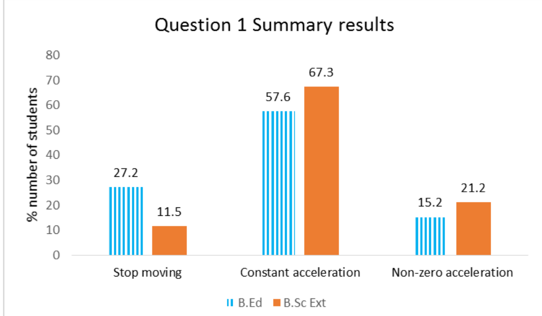

Figure 3. Question 1 results

The results on figure 3 shows that 57.6 % (19 students) of B.Ed. program students and 67.3% (70 students) of BSc extended program students chose correctly, but about 100 % was expected since the topic was covered in high school and then revised at tertiary institution, it was expected that students would answer correctly and justify their choices using the relevant physics law. For example, we expected their answers to be as follows: correct choice, state the law and then use the law to justify their answers. The correct answer for the question was option B (acceleration is constant), looking at answers students gave as their explanations for their choices, their explanations revealed that they were unable to clearly justify their choices, to apply physics laws correctly while justifying their choices. For example, one of the students' explanations about their choices in question 1 was as follows: *"The object will move at a constant acceleration because the object will move at a constant velocity unless acted upon by an unbalanced force"*. The explanation revealed that some students do not see constant force as an unbalanced force which is a misconception. Further analysis of students' incorrect explanations revealed that some still held that constant force implied a constant speed or velocity and others revealed that they think on frictionless surface the speed is constant. Other students were unable to state Newton's second law correctly because they state that the net force is directly proportional to acceleration, which should be the opposite.

3.2. The impact of equilibrant/ net force on moving object.

The question probed student's understanding of the impact of equilibrant force when an object is accelerating as shown in figure 4, which was about newton's first law. The question was as follows:

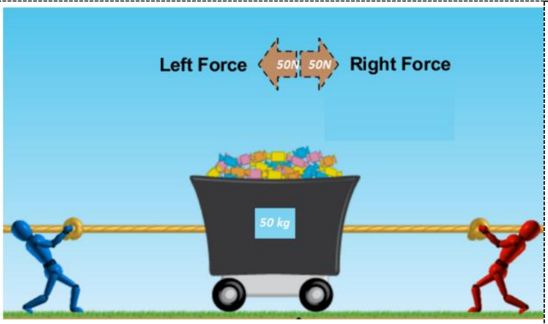

Figure 4. Simulated diagram for question 2.

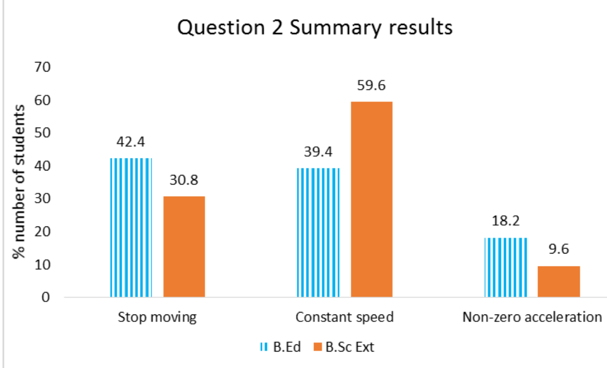

Figure 5. Question 2 results

"The person exerts a force of 50 N and the cart was set in motion to the left, while in motion another person exerts a force of 50 N to the right, what do you think will happen to the motion of the cart?" Students' options in percentages are shown in figure 5.

The results in figure 5 show that 59.6% (62 students) of BSc Extended program chose the correct answer when compared to 39.4 % (13 students) of B.Ed. program students. We expected students to use Newton's first law to justify their choices. However, the results revealed that some students associated net-zero force with only objects at rest as indicated by the response written by one of the students: "*We have the resultant force of zero so the cart won't move due to zero acceleration*". Students' incorrect choice and incorrect explanations revealed that they still have misconceptions about the necessity of the net force to sustain motion [7-9]. Others explained that when forces are balanced, an object stops, which shows that they do not know how to apply Newton's first law.

3.3. The impact of additional mass on horizontal motion

When the constant net force was maintained, an additional mass of 50 kg was added as shown in figure 6, students were probed to choose and explain their answers. The question was tricky in such way students were expected to reason based on the overall impact of adding 50 kg on the resulting motion. The most appropriate answer was that the resulting motion would have a constant acceleration because the net force was still constant after the addition of a 50 kg. Figure 7 revealed that few students 21.2 % (7 students) B.Ed. students and 19.4 % (21 students) BSc extended program students answered correctly.

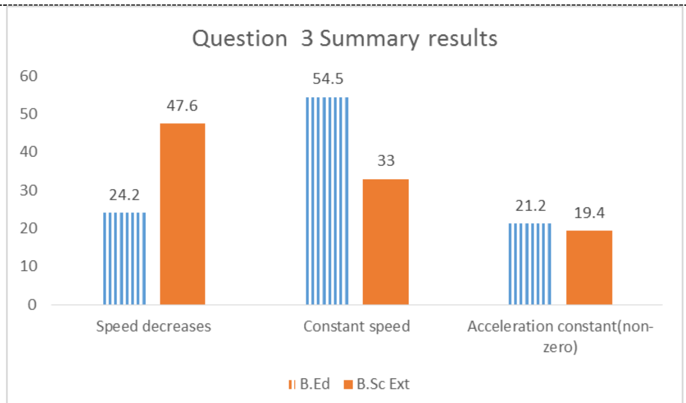

Figure 6. An additional mass of 50 kg added to the trolley.		**Figure 7.** Question 3 results

3.4 The impact of friction on the motion of an object.

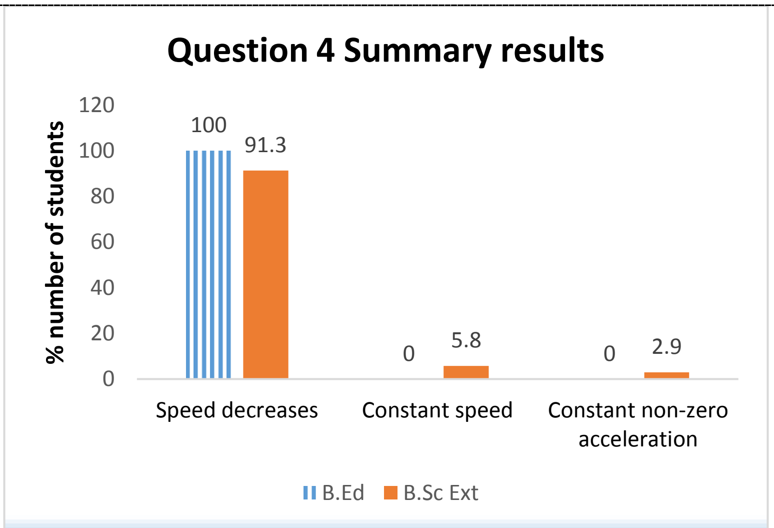

Figure 8. Question 4 results.

This was the follow up of the previous questions. It was framed as follows: *If the box of mass 50 kg is added to the cart in question 3. What do you think will happen to the motion of the cart if the surface where tires are moving is rough?* We expected students to explain that the net force would gradually decrease and hence causing the motion to slow down. According to figure 8, all B.Ed. students answered correctly while very few 8 BSc program extended students did not answer correctly. The results suggest that the impact of friction on a moving object was well understood by students.

4. Conclusion

Through the analysis of the students' explanation about a real context simulated from PheT program, some of the challenges students experienced were revealed when many students were unable to justify their options using the correct physics law(s) or principles, it is suggested that in future, instructors use scientific explanations models to develop students' reasoning skills.

Table 1. Students' with correct choices in numbers and percentages.

	B.Ed. (N =33)	%	BSc (N =104)	%
Q1	19	57.6	70	67.3
Q2	13	39.4	62	59.6
Q3	7	21.2	21	19.4
Q4	33	100	95	91.3

Students' inability to state Newton's second law correctly can be avoided if instructors revise the importance of dependant and independent variables. The results of this study revealed that even after an introductory physics at university has been covered, students still have the misconceptions they had after instruction. A first question is of importance in assessing students understanding of the concept of constant force. We observed that, on average the understanding of this concept differs by 10% from both groups results. This agrees with figure 1 observation that there was no significant difference between BSc and B.Ed. student's physical science results. Concerning question two results, we noticed that students understanding of Newton's first law was not well understood by 60.6% (20 students) of B.Ed. program and almost 59.6% (62 students) of BSc program shown understanding of Newtons first law. Results in question 3 are consistent with [7] who indicated that majority of misconceptions remained unchanged. About 78.2% and 80.6% of both B.Ed. and BSc program students respectively failed to get the correct answer. More time given in the teaching of these concepts and understanding of Newton's laws in conjunction to simulations could be help students to answer these kinds of questions correctly. Understanding of vectors could be a contributor to apply Newton's laws correctly. It can be concluded that majority of both B.Ed. program and BSc extended program students were incompetent on applying both Newton first and second laws of motion but were competent in understanding the impact of friction on the moving object. If the emphasis of understanding and interpretations of Newton Laws not realised by students in the first-year level. It might also perpetuate misconception on the applications and affect sustainable conceptual change among physics first year students.

5. Acknowledgements

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