Is there a gap between the high school curriculum and first year university experience?

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Abstract. The transition of high school curriculum from the previous Senior Certificate Examination (SCE) (which offered both Higher Grade (HG) and Standard Grade (SG)) to National Curriculum Statement (NCS) (subjects offered at one level) yielded in a number of learners who pass their National Senior Certificate (NSC) with the minimum admission point score (APS). However, the expected knowledge and understanding of the content of the subject matter is rather contrary. This has been a recent observation experienced by first year physics lecturers at University of Johannesburg (UJ). One area of difficulty for the first year students is the basic understanding of vectors. A study performed previously indicated that some intervention(s) were necessary in an endeavor to improve vector concepts' understanding. A study performed indicated that most of the students treated this section in their NCS level, yet the application of the knowledge to their first year physics and to the related concepts is problematic for most students. This study reports on the outcomes obtained from interventions employed within the first semester of the four year physics lectures at UJ.

1. Introduction

After the outcome of our study that is reported in [1], there was a need to engage on a short term, short scale investigation of students understanding of vectors. In this study, we examined the implications of time factor in teaching vector sections. These time factors were looked at against times spent in treating these sections as stipulated by the National Curriculum Statement(NCS) for physical science. In this search, it was observed that the curriculum contains and provides enough topics to manage the first year mechanics course at university. The Further Education and Training (FET) physical science revealed that, vector related sections are taught only in four hours as stipulated in Physical science Curriculum and Assessment Policy Statement (CAPS) [2]. The vector section is taught in grade 11 academic year within the first quarter and momentum is taught in second quarter of their grade 12 studies where thirteen hours are spent on this section. We further examined the ability of students to determine and use qualitatively the magnitude and direction of the vector from knowledge of drawing a free-body diagram at first year level at UJ. The use of vector components concepts to draw free-body diagrams are basics to most mechanics problems. The lecturers in the first year extended programme spent more time in teaching the vector related concepts. The students were encouraged to be actively involved in drawing free-body diagrams and the addition of vectors. It was intended to emphasize to students that the vector nature of forces, fields, and kinematics quantities requires that students have a good grasp of basic vector concepts if they are to be successful in mastering introductory level physics [3].

Student learning is our primary criterion for determining teaching effectiveness. Lectures were taught in an interactive manner and the use of their own experience in applications of vector knowledge. Questions related to this section and beyond, were treated in lectures and during the tutorial sessions. In lectures, it was observed that some students struggled with drawing of vector diagrams when given in different orientations. During the tutorial sessions, some more active learning was encouraged to students by insisting to them to draw their own free-body diagrams and present them to other tutor group members. It must be mentioned that the tutorial sessions at UJ take place every second week for each tutorial group and are managed in conjunction with two senior student tutors in each session. Despite most students' being exposed to drawing of free-body diagrams, still misconceptions and difficulties related to vectors are observed. This study suggests that instructors in introductory physics course must give explicit consideration to students' conception development in the learning of vectors.

The aim of this study was to investigate the causes of unsatisfactory performance on the sections involving vectors in basic mechanics. The objective of this study was to examine the ability of students to draw free-body diagrams and interpret them in relation to the given problem and be able to manipulate basic mathematics and to successfully solve the problem. The questions were designed to measure students' knowledge on basic level of vectors; it contained the drawing of the free-body diagram, addition of vectors algebraically and graphically, expressing vectors in terms of magnitude and direction using trigonometric functions to calculate the direction of the vectors.

2. Methodology

Initially, a questionnaire was given where the focus was on three questions listed in the table 1. The general physics skills test of 20 multiple choice questions was also given to students in the end of the course to check if the students gained the basic knowledge of vectors and are able to apply to fundamental mechanics topics. Five questions of the 20 multiple choice questions were designed to measure students' knowledge of basic level of vectors, these questions were based on kinematics, addition of vectors algebraically, expressing vectors in terms of magnitude and direction. Further similar questions including problem solving questions were given to students through the course and were finally given a familiar question in the final semester examination to determine whether conceptual understanding was gained. The tests were administered to 192 four year physics 1 students from UJ. Only 138 students wrote the physics skills test (PST) and 161 qualified to write the final exam. The specific question to be studied in the examination was marked by one lecturer and was moderated by the other lecturer teaching the module and internal examiner from the physics department. The above mentioned question was intended to examine if students could draw the correct free-body diagram and calculate the acceleration of the two given objects.

3. Results

After the assessment of CAPS and the establishment of what the students have learnt in high school; added to the 12 hours of formal lecturing and 9 hours of tutorial sessions the understanding of students on vector topic was tested. The questionnaire responses of the students listed in the table, gave hope that the students will be performing well in this topic. In their responses, in Q1 it is indicated that 15% of students mentioned that there was nothing to be unlearnt, leaving a large percentage of students who had to unlearn some concepts.

3.1. Survey Questions

- **Q1**: Are there any areas of PHY1 extended in which you had to unlearn concepts you had previously learnt at high school? **Yes/No**.
  If so, please specify the concept(s).

- **Q2**: Are there any areas of PHY1 extended which assumed knowledge of concepts that you had not previously met? **Yes/No**.
  If so, mention those areas.
- **Q3**: Are there any areas of PHY1 extended that repeated material that you had already thoroughly mastered at high school? **Yes/No**.
  If so, please elaborate.

In the response of Q2, it is indicated that 21% of students have previously learnt something on vectors, implying that they were not coming across these topic for the first time. This is a further positive result, expected to yield better pass rate and throughputs. This is further supported by the response of Q3, where it is portrayed that 41% were repeating the material. These were further positive indicators about the group of students we had. Closer look at Q2 and Q3, point to the same conclusion, which could be summarised as; 62% in our group of students have seen and treated some vector related problems in their high school curriculum.

Table 1. A table listing the specific questions and responses of the survey taken after the lecturing of vector section.

Question	Responses (%)
Q1	15
Q2	21
Q3	41

The analysis of the four year physics degree program for the first semester results of 2013 at UJ is presented below. These results were carefully looked at considering the academic background of the students. Figure 1 shows the accompanying diagram of the question (left hand side diagram) and the histogram (right hand diagram) showing the results of the responses of the question outlined below. The question, the codes and responses of these options from which the students had to choose from are also shown below.

Question 1: A small box X is moving on a horizontal frictional surface towards a stationary heavier box Y. After the boxes collide they rebound off each other. Some heat is generated during this collision. Which of the following must be true after the collision?
Below are the options from which the students had to choose from for the above given question in figure 1.

- **1**: The speed of X is zero and Y moves to the right.
- **2**: X moves to the left and Y moves to the right.
- **3**: Both X and Y move to the right.
- **4**: X moves to the left and Y remains stationary.
- **5**: We need more information to determine which box moves after the collision, and in which direction they move.
- **6**: I do not know the answer because I do not understand the Physics in this question.
- **7**: I do not know the answer because I do not understand some of the words used in this question.
- **8**: Unanswered.

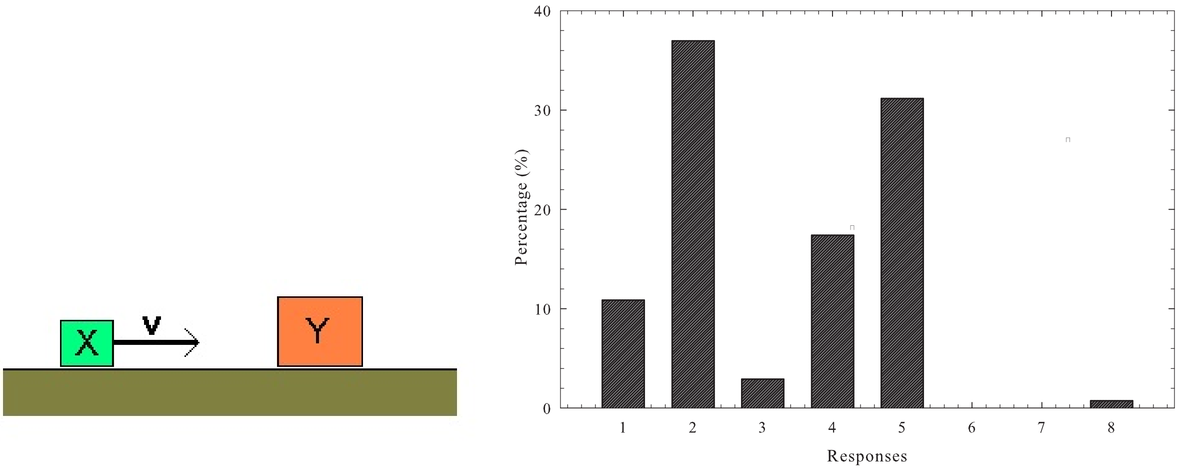

Figure 1. (Left) A diagram used in clarifying question 1 and the histogram (Right) presenting the data of the number of students in percentage form, against students' responses, *the momentum problem.*

It is observed that most students chose option 2 followed by the response from option 5. Most students (about 37%) believe that the small box X will move to the left while the big box Y will move to the right. It is clear that these students have an idea of momentum concepts, but they still struggle to read the question carefully to get all relevant information needed to solve the problem. The realities of the differences in masses, the velocities, including the fact that the big box Y is initially stationary were not considered. It is evident that the students did not consider that the surface is frictional. It is only 30% of the students who managed to observe that more information is needed to successfully solve the problem. It is also very interesting to learn how students respond to the problem of an inclined plane.

Question 2: A box is placed on a frictionless incline (see diagram). Which arrow best describes the direction of the force of reaction exerted by the incline to the box?

A number of vector components are involved in the system, whether the system is stationary or will be in motion. It was also established that there is still a lot of misunderstanding on the use of words like "by", "to". The question asked had "B" or option "2" as the correct response. Only 28% of students gave the correct response. These students managed to understand that the question was referring to the ground as opposed to "slope" as implicated from the responses of students who chose "A" (1) and/or "D" (4).

Question 3: A block is held stationary in equilibrium against a rough vertical wall by a horizontal force (illustrated by the black arrow in the diagram). Which arrow in the right diagram best illustrates the direction of the frictional force acting on the block?

These responses bring an understanding that the students have less understanding of the use of vectors (lines and arrows) and their effect on the system. The lack of understanding in the use of lines and arrows in indicating what happens onto the system, poses a challenge in the way vectors should be presented to first year level students.

Another challenge was identified after the students' response of question 3, which is presented in figure 4. Although 40% of students managed to get the answer right, an equal number of

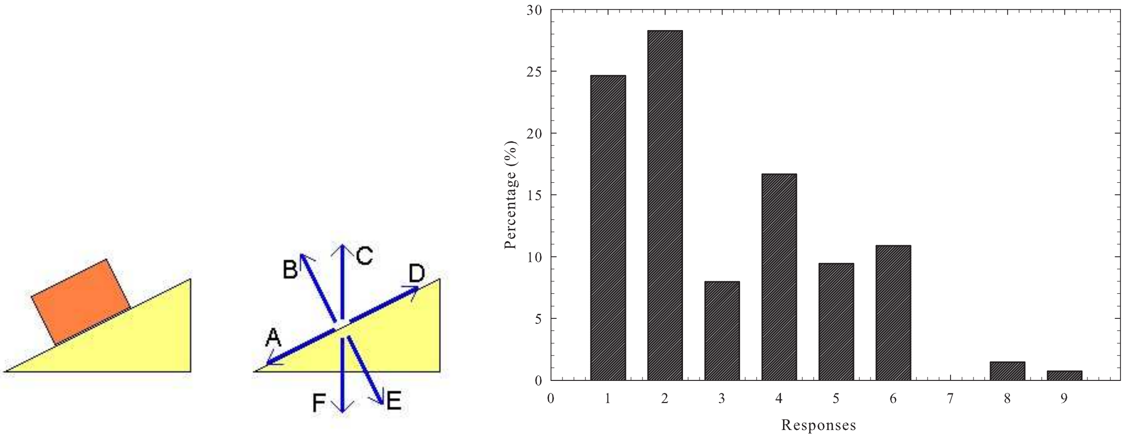

Figure 2. (Left) A diagram used in clarifying question 2 and the (Right) histogram presenting the data of the number of students in percentage form, against students' responses, *the inclined problem.*

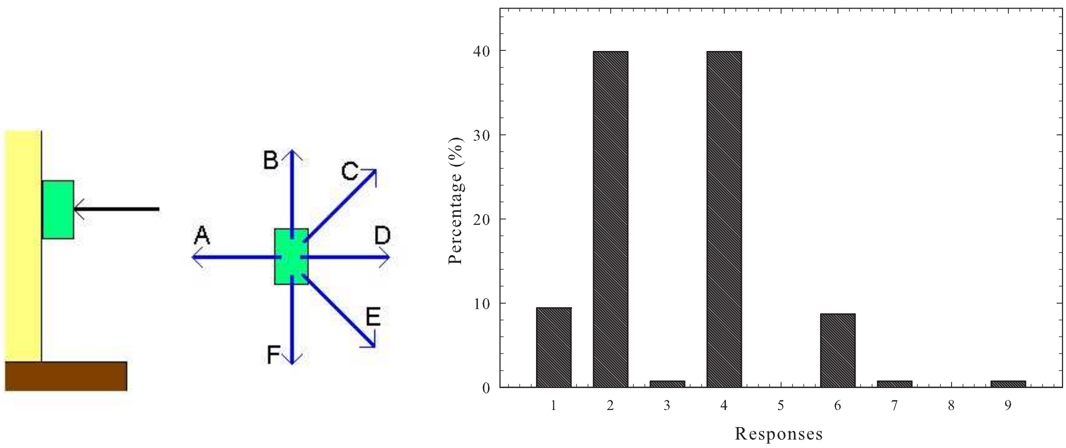

Figure 3. (Left) A diagram used in clarifying question 3 and the (Right) histogram presenting the data of the number of students in percentage form, against students' responses, *friction against the wall problem.*

students gave a response which eluded that the students are still mixing up concepts. This latter group of students' responses imply that only the opposing force or vector should be in the same axis, but in the opposite direction. As mentioned above, tutorial sessions were actively employed as intervention means after the outcome of the survey was performed. Figure 4 gives the results obtained from that investigation. Only 20% of the students who wrote the exam, managed to get the question correct, that is, only 30 out of 161 students that wrote an exam. The histogram shows the distribution of their marks from the minimum mark of 50% to the maximum of 100%. The fourth column in table 2 indicates these marks distributions. It is shown that in this percentage of students that passed, 14 of them got the maximum marks, and 7 of them got the marks between 70 and 80%.

Table 2. A table listing the codes used in figure 2, 3 and 4.

Codes	Choices (Question 2)	Choices (Question 3)	Ranges of Figure 4 (%)
1	A	A	50-59
2	B	B	60-69
3	C	C	70-79
4	D	D	80-89
5	E	E	90-100
6	F	F	-
7	I don't know	I don't know	-
8	I don't understand	I don't understand	-
9	Unanswered	unanswered	-

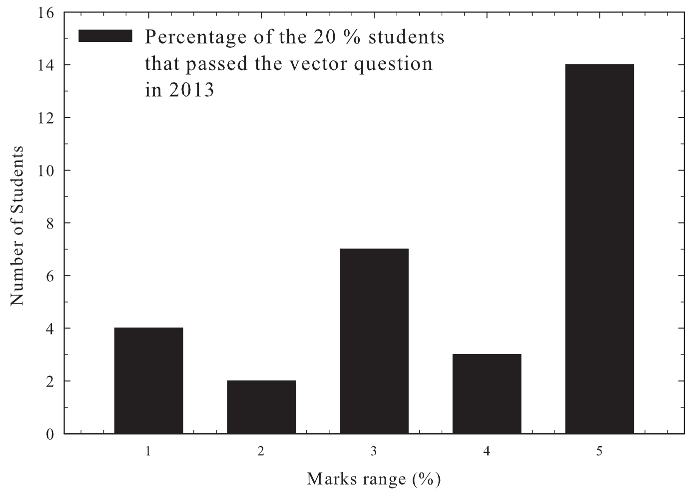

Figure 4. The percentage of students who passed the vector problem as written in the first semester exam.

4. Conclusion

The results of the investigation in this regard seem to suggest that students generally experience difficulty in vector-related problems. This is despite the fact that the basic concepts in this section have been introduced at high school level. Although this is expected to be advantageous and beneficial to the students, the contrary is observed. The students seem to assume that the concepts are familiar and as a result less attention is paid in the simulation of fundamental concepts related to this section. This was evidenced by the 20% performance obtained from the exam question. Further investigations are ongoing in trying to enhance the understanding of the vector-related fundamental concepts.

5. Acknowledgements

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