INVESTIGATION OF PROBLEM AREAS IN VECTORS AS EXPERIENCED BY FIRST YEAR UNIVERSITY STUDENTS

Buyisiwe M Sondezi and Paul Molefe
Physics Department, University of Johannesburg, South Africa,
Email: bmsondezi@uj.ac.za

Abstract

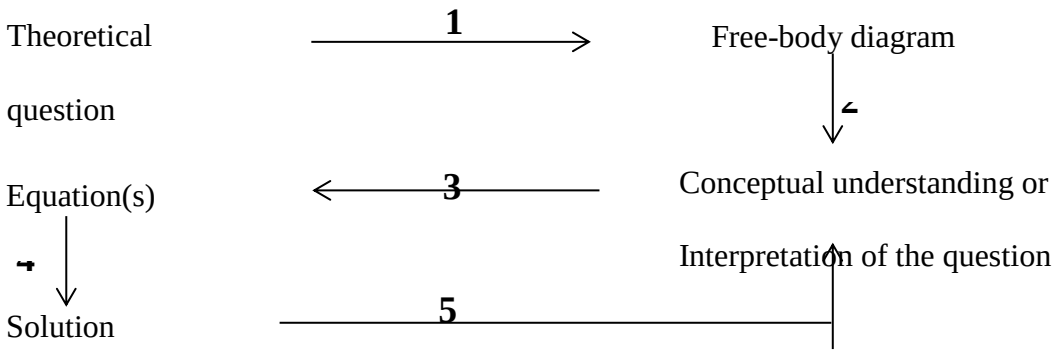
It has recently been observed that the number of learners who pass their National Senior Certificate (NSC) with the minimum admission point score (APS) is increasing. This is the case despite the fact that subjects at matriculation level are now offered at one level as opposed to the previous Senior Certificate Examination (SCE) (which offered both Higher Grade (HG) and Standard Grade (SG)). However, it has been observed that 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. The Physical Science Curriculum and Assessment Policy Statement (CAPS) from the Department of Education (DoE) has been consulted with the aim of establishing the contents done in Further Education and Training (FET) band. A study was undertaken whereby diagnosis of the problematic areas in this section of vectors was investigated. This paper reports on the findings of that diagnosis test.

1. INTRODUCTION

In our initial report (Molefe & Sondezi-Mhlungu, 2012), it was indicated that the section that deals with vectors in the first year university level needed more attention. There was a need to engage on a short term, short scale investigation of students' understanding of vectors. In our previous work it was eluded that the basic vector definition describes a vector as a quantity with both magnitude and direction, which is represented geometrically by a directed line (length of the line representing the magnitude; and an arrow representing the direction of a vector). The use of vectors in both forces and equilibrium concepts illustrated by free-body diagrams, are basics to all mechanics problems (Knight, 1995). In this study it has been established that the FET curriculum contains and provides enough topics to manage the first year mechanics course at university level. The observation of Physical Science Curriculum and Assessment Policy Statement (CAPS) (DoE, 2012) revealed that the Newtonian mechanics vector sections, particularly a section in forces are initially encountered by learners in grade 11. The vector sections are continued in grade 12 academic year where the sections on Newton's second law expressed in terms of momentum, conservation of momentum and impulse, 1 dimensional (1D) and two dimensional (2D) projectile motions, and work, energy and power topics are taught. Generally, it has been reported that students experience difficulty in understanding this section (Nguyen & Meltzer, 2003). This was observed as a troublesome obstacle to the success of the

students in mastering physics concepts. The difficulty has been on the graphical and free-body representation and interpretation of vector ideas which subsequently translate to the understanding of general physics concepts.

After the observation of unsatisfactory performance(s) on the sections involving vectors (forces) in basic mechanics; we then embarked on a study where we examined the ability of students to determine and use qualitatively the magnitude and direction of vector(s). These are looked at from the stage where students are expected to extract the correct information from the question and be able to draw a free-body diagram. It is from this stage that the students' ability to properly conceptualise and interpret the question is further assessed. The equation(s) written from the diagram(s) determines whether the students fully understand the concepts related to this section. This study was undertaken to students enrolled for first year level at UJ. The sketch below is the graphical representation of the framework used in the investigation during this study, where different stages are shown.



2. METHODOLOGY

2.1 Sample

The data used in this study was collected from 192 first year foundation (first year extended degree) students. This group of students were enrolled for the abovementioned module in the first semester of 2013 academic year at UJ.

2.2 Data Collection

The data that were analysed from our focus group were obtained from a list of questionnaires, from the Physics Skills Test (PST) that was written at the end of the module and from the mid-year exam. From the questionnaires students' responses, the focus was on the three questions

which are listed below. We selected three vector-related questions of interest from the PST and one vector-related question from the exam.

Questionnaires

The questions used in this section were deliberately designed to find students' previous knowledge and understanding of the topic under investigation. Out of the 192 students enrolled in this course, only 165 students participated in these survey questions.

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.*

PST

From the 20 multiple choice questions that were given to our focus group through e-learning system used at UJ, only 138 students responded to the test, that is, 72 % of the total number of enrolled students in this module. These PST questions were designed to measure students' knowledge on basic level of vectors; it involved the interpretation of free-body diagrams, addition of vectors algebraically and expressing vectors in terms of magnitude and direction using trigonometric functions. The questions of interest from PST test are outlined and discussed in the results sections.

Exam question

A question on inclined plane was given to the focus group, of which 161 students had an opportunity to write the mid-year exam. Approximately 80 % of these students got less than a pass percentage (<50 %) on the question under investigation. This specific question was marked by one lecturer and moderated by two staff members, the lecturer teaching the module and an independent member from the physics department.

3. RESULTS

Survey questions results

The analyses of the survey questions gave positive responses and hope that the students will be performing well in vector-related topics. Table 1 lists the responses of the survey questions (Q1, Q2 and Q3) shown above.

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

Questions	Responses (%)
Q1	15
Q2	21
Q3	41

Table 2: A table listing the codes used in figure 1, 2 and 3.

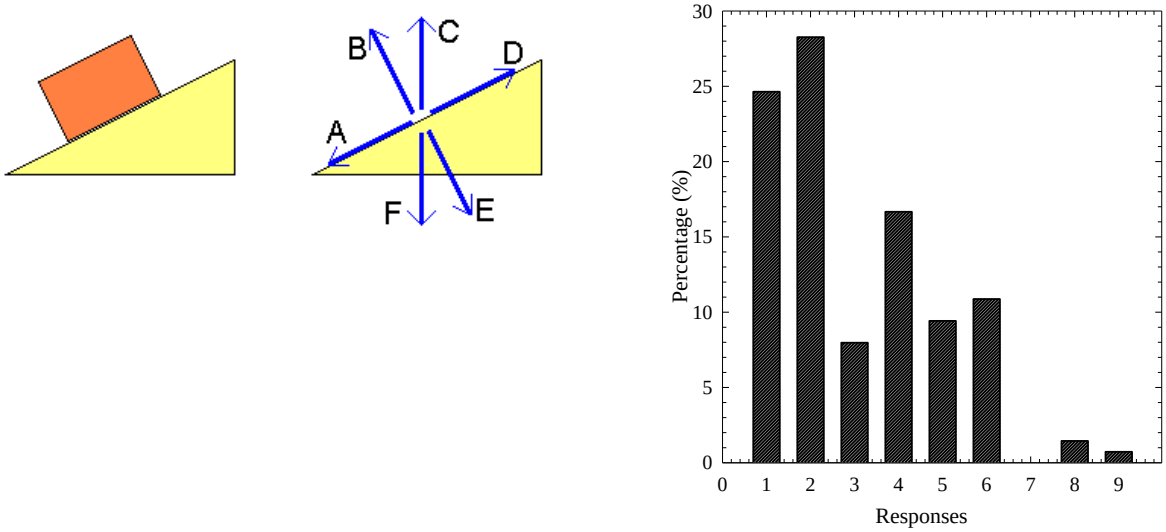
Codes	Choices (Q1)	Choices (Q2)	Ranges of Figure 3 (%)
1	A	A	50 – 59
2	B	B	60 – 69
3	C	C	70 – 79
4	D	D	80 - 89
5	E	E	90 - 100
6	F	F	-
7	I don't know	I don't know	-
8	I don't understand	I don't understand	-
9	Unanswered	Unanswered	-

PST Results

Question 1: *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?*

Figure 1: (a) A diagram used in clarifying question 1 and the (b) histogram presenting the data of the number of students in percentage form, against students' responses.

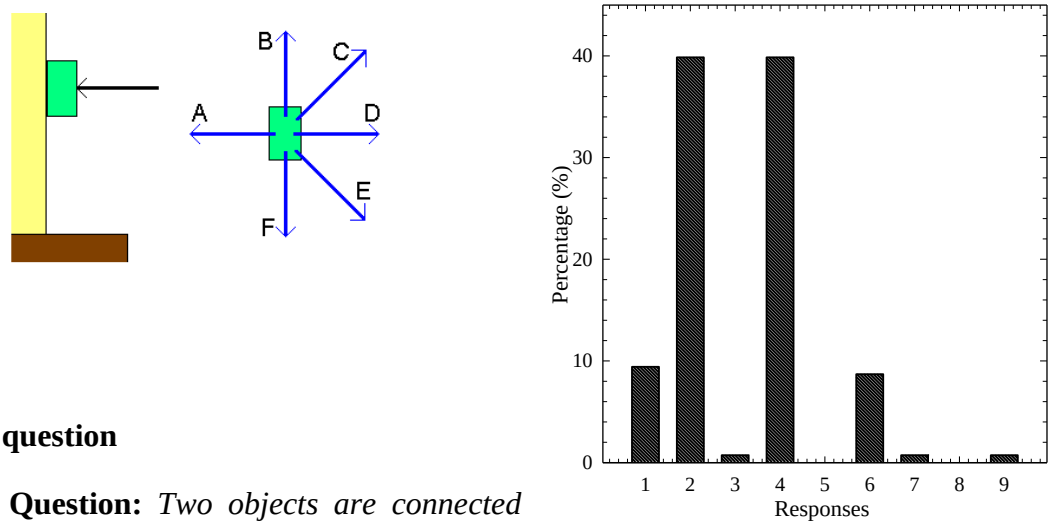
(a) (b)



Question 2: *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?*

Figure 2: (a) A diagram used in clarifying question 2 and the (b) histogram presenting the data of the number of students in percentage form, against students' responses.

(a) (b)



Exam question

Exam Question: *Two objects are connected by a light string that passes over a frictionless pulley, as in figure 3 (a). If the incline is frictionless and if m_1 = 2.0kg, m_2 = 6.0kg, and □□□□55.0°. With the aid of free-body diagrams of both objects, calculate:*

a) the accelerations of the objects.

b) the tension in the string.

c) the speed of each object 2.0 s after being released from rest.

Figure 3: (a) An exam question testing students' understanding on vectors and (b) the histogram showing the performance of students who responded correctly to the vector question.

(a) (b)

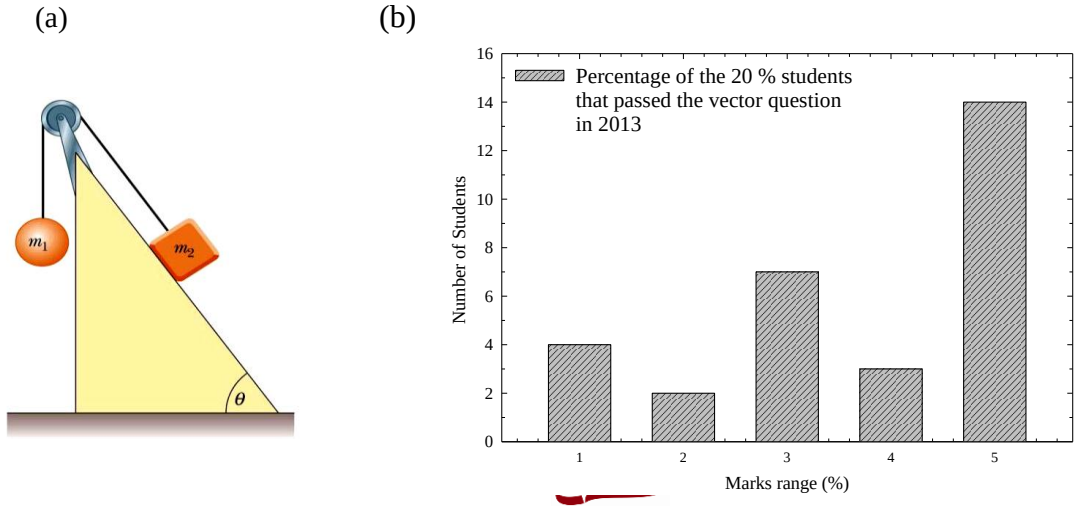
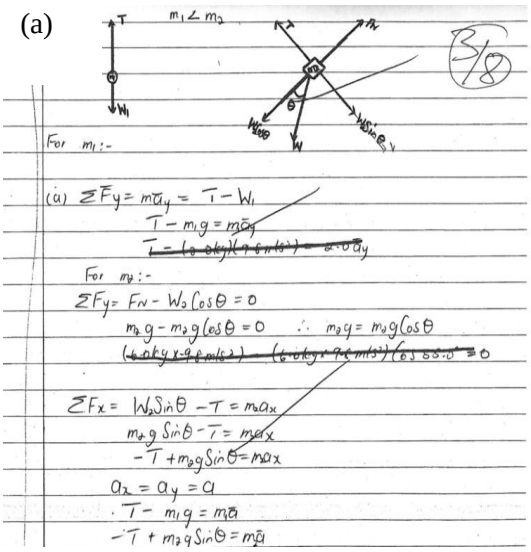
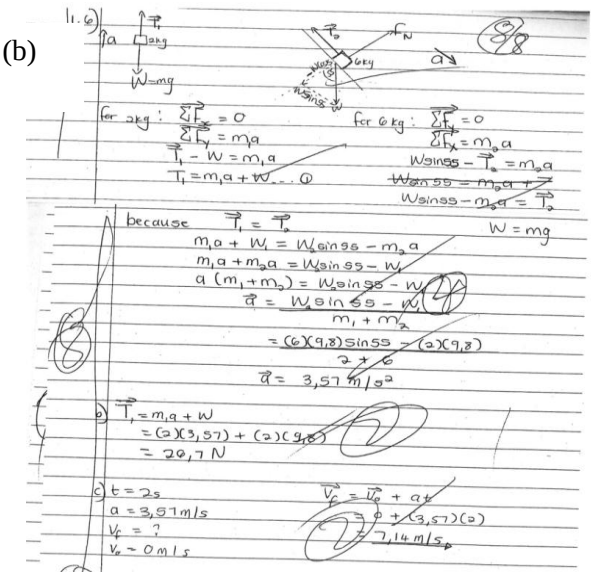


Figure 4: Scanned copies of the answer sheets with responses of PHY1 for the exam question on inclined plane.

(a)



(b)



DISCUSSION OF RESULTS

The three sets of collected data will be discussed in this section. All percentages indicated in this study are given as a number of those students who participated in a particular question and the responses of students as outlined in table 2.

Questionnaires

The response of Q1 resulted in 15% of students indicating that there was nothing to be unlearnt, leaving a large percentage of students who had to unlearn some concepts. The response of Q2 indicates that 21% of students have previously learnt something on vectors, implying that they were not coming across this topic for the first time. This is a further positive result, expected to yield better pass rate on the section(s) under investigation. This is further supported by the response of Q3, where it is portrayed that 41% were repeating the material. 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.

PST

The analyses of the PST results of 2013 at UJ are presented below. These results were carefully looked at considering the academic background of the students. Figure 1 (a) shows the accompanying diagram of the question and the response in a form of a histogram (figure 1 (b)).

The question, the codes and responses of the options from which the students had to choose from are shown in table 2.

A number of vector components are involved in the system, to determine whether the system is stationary or will be in motion. The responses of the students to this question represented by figure 1 (a) are shown in figure 1 (b). Only 28% of students gave the correct response, where the response was "B" or option "2". Since most students could not get the answer correct indicated that there is still a lot of misunderstanding on the use of words like "by" and/or "to". However, it is observed that about 25% of students chose option "A"(1) and about 17% chose "D"(4). These two responses, "A" and/or "D" both have an element of causing the motion on the object on an inclined surface. The use of words and concepts in these responses are perceived as the source of misunderstanding.

The accompanying sketch for question 2 is shown in figure 2 (a) whilst the students' responses are shown in figure 2 (b). The histogram reveals that most responses are split between options "B"(2) and "D"(4) whilst "B" is the correct response. These responses inform that students have less understanding about the use of vector laws and their effect on the system. Students still use Newton's laws interchangeably without proper analysis of the problem. Although 40% of students managed to get the answer right, an equal number of students gave a response which eluded that the students are still mixing up concepts. This latter group of students' responses imply that the only opposing force or vector should be in the same dimension (axis) but in the opposite direction. In this assumption by the students the contribution of frictional force between the wall and the block, is ignored and hence the wrong conclusion is drawn.

Student learning is our primary criterion for determining teaching effectiveness. Lectures were taught in an interactive manner and the use of their own experiences in applications of vector knowledge was utilized. In lectures, it was observed that some students struggled with drawing of vector diagrams when given in different orientations. Tutorial sessions were actively employed as an intervention means after the outcome of the survey performed and PST. 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 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.

Exam question

As means of testing effectiveness of the intervention especially in this section, a specific vector question was later given to the students as part of their mid-year exam. Figure 3 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 who passed, 14 of them got the maximum marks, and 7 of them got the marks between 70 and 80%. It is observed from this analysis that the students seem to have grasped the concept of drawing free-body diagrams before attempting to solve vector problems. This is evidenced by the attached students' responses (see figure 4 as obtained from the exam question. Both students' responses show an acceptable level of understanding of vector representation of the problem in question.

However, in an attempt to move towards solving the problem, the response on the left hand side of figure 4 shows that there are still some areas that need more attention. These areas of concern involve the understanding of resolving vector components, addition of vectors and sticking to correct application of mathematical concepts. The student's response on the right hand side of the figure is the representation of the responses obtained from a handful of students who managed to get maximum marks from this problem. It is impressive to observe the solution from the correct use of free-body diagrams, resolving of vector components, and proper addition of vectors and correct application of mathematical concepts.

5. CONCLUSION

This expected pre-conceived knowledge for the first year university experience in physics is informed by CAPS which indicates that students were introduced to the concept of vectors as early as grade 10 school curriculum level (DoE, 2012). The initial assessment in this study was performed through survey questions, supported this expectation, although PST results almost gave contrary results where misconceptions and misinterpretations were identified. This observation is further supported by the results of the exam question that was analysed (see figure 4), both students showed an acceptable knowledge of drawing free-body diagrams (that is, they managed to move from stage 1 to stage 2). The difference is observed in the translation of the information from the diagram into an equation (stage 3 to stage 5), which is seen as inability to adequately interpret or extract relevant information from the free-body diagram (see figure 4a). Figure 4b is a representative response of those students who managed to read and understand the question, to draw free-body diagram correctly and to extract correct information from the vectors drawn and the ability to write correct equations that to proper addition of vectors and subsequently get to the solution that is, moving from stage 1 to stage 5 successfully.

The results of this study suggest that most students in the physics extended degree still experience difficulty in their first year university experience. The section on vectors has been the major concern and the area of difficulty. Despite this finding, it is observed that a handful of students are able to tackle this section efficiently following all necessary steps to get to the solution. Most students were found to be managing well with the drawing of the free-body diagrams, although some difficulty is still widely experienced when proper execution of the whole solution process has to be undertaken.

Acknowledgements

The authors acknowledge Prof. H Winkler and the assistance from the department of physics at UJ.

References

DoE. (2012). *Curriculum and Assessment Policy Statement (CAPS).* Department of Education, Government Gazette.

Knight, R. D. (1995). The Vector Knowledge of Beginning Physics Students. *The Physics Teacher, 33,* 74-77.

Molefe, P., & Sondezi-Mhlungu, B. M. (2012). Investigating the causes of unsatisfactory performance on the section involving vectors in basic mechanics. *57th Annual Conference of South African Institute of Physics Proceedings,* In Press.

Nguyen, N., & Meltzer, D. E. (2003). Initial understanding of vector concepts among students in introductory physics courses. *American Association of Physics Teachers, 71 (6)* , 630-638.