The pre-knowledge of the physics I students on vectors

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Abstract. The purpose of this study was to investigate the pre-knowledge of the Physics I students on vectors. The study was conducted on 234 Physics I students from the University of Limpopo (Medunsa campus). The sample was divided into four groups, where the first group (n = 119) did their grade 12 in 2010, the second group (n = 46) did their grade 12 prior 2010, the third group (n = 42) did Foundation Physics in 2010 and the fourth group (n = 27) were those repeating Physics I. An ex post facto research design was chosen for the study whereby all the groups were given a vector test at the beginning. The test was divided into three questions, testing definitions, classifications, drawing and interpretations of graphs. Results showed a less difference between average percentage of the groups whereby the group before 2010 (47.4%), foundation group (47.3%), the repeaters (44.3%) and those who did grade 12 in 2010 (44.1%).

1. Introduction

A vector is a quantity with magnitude and direction that is represented geometrically by a directed line segment, i.e., an arrow [1]. Vector concepts and calculation methods are the core of the physics curriculum, underlying most topics covered in introductory university physics courses. [5] emphasized that the vector nature of forces, fields, and kinematical quantities requires that students have a good grasp of basic vector concepts if they are to be successful in mastering even introductory-level physics. The primary concept of Newtonian mechanics is force, and forces are vectors, they should be added using vector addition to determine the net force along the axis of motion.It appears that most of students' knowledge in the university level is brought from high school physics [6]. There are considerations that the idea of vector has different meanings in different contexts and therefore it is not easily transferable from one context to another.

Unlike scalar quantities such as temperature, mass and time, the mathematical manipulation of vectors is somewhat more complicated. For a typical introductory mechanics course the topics to be studied include areas such as kinematics, dynamics and Newton's Law of motion, work and energy, impulse and momentum, and rotational motion. In order to reach a sound understanding of the concepts presented in these topics a basic understanding of vector algebra is also needed [2].

There are suggestions in the literature that a qualitative approach to teaching would help students to learn. The Hestenes and Wells Mechanics Baseline Test look at the directional aspects of kinematic vectors and at the superposition of force vectors and the lowest scores were reported in the questions that required an understanding of vector properties [3]. [7] reported on students learning difficulties related to basic vector operations as employed in introductory physics courses.

In the study [6] found that ¼ of students who had completed a calculus-based physics course and ½ of students who hadcompleted an algebra-based physics course could not add vectors in two dimensions. British study [8] indicates that, "in spite of clear instruction inprocedures for vector addition, many students 'forget' to draw the final side of thetriangle (the resultant) when finding a vector sum, or have difficulties when vectors are in non-standard positions (i.e., crossing one another or pointing at the same point)".

All these studies suggest that students seem to have their own ways of conceptualizing the vector concept. Despite most students' previous exposure to vector concepts, there are still misconceptions and difficulties related to vectors. These studies suggest that instructors in introductory physics courses must give explicit consideration to students' familiarity with and learning of vectors. The question raised is how much do the students know before doing the introductory physics at the university? To answer the question, we have developed a *vector test*which was moderated by two external assessors who are expects in the field, and given it to University of Limpopo (Medunsa campus) physics I students at the beginning of the semester.

2. Methods

To investigate the students' pre knowledge of vectors, the vector test was developed. The goal of the test was to see if the students possess the basic knowledge of vectors that will allow them to understand kinematics or Newtonian mechanics. The test was designed to measure students' knowledge on basic level of vectors. Its aim was to check whether students can: add vectors algebraically and graphically, classify as vectors or scalars, express vectors in terms of magnitude and direction, and use trigonometric functions to calculate vectors.

The test was divided into three sections. The first section was a multiple choice questions consisting of twenty questions with four options to choose from. The second section was classifying as vectors or scalars. It consisted of ten questions. The third section was calculations, where magnitude and direction were determined both algebraically and graphically. In the graphical representation, the graph paper was used and the graphs were expected to be drawn according to scale.

The test was administered to 234 physics I students from the University of Limpopo (Medunsa campus). The sample was divided into four groups, where the first group (n = 119) passed their grade 12 in 2010, the second group (n = 46) passed their grade 12 prior 2010, the third group (n = 42) did Foundation Physics in 2010 and the fourth group (n = 27) were those repeating Physics I.The students who participated in this study are not doing the same courses. Some are doing mathematics, others are intending to do physics as their major course, and majority are just doing it as a non-major course.

3. Results

The test was administered before the students could attend physics classes at the beginning of the year. The knowledge tested in this study was the knowledge acquired from the previous levels. The average score of the whole class was 45.8 % for the entire test. The groups did not show much difference in terms of their averages. Figure 1 below shows the average performance of the individual groups. The foundation group and the prior 2010 groups scored 47.3% and 47.4% respectively whereas the matric 2010 and the repeaters scored 44.3% and 44.1% respectively.

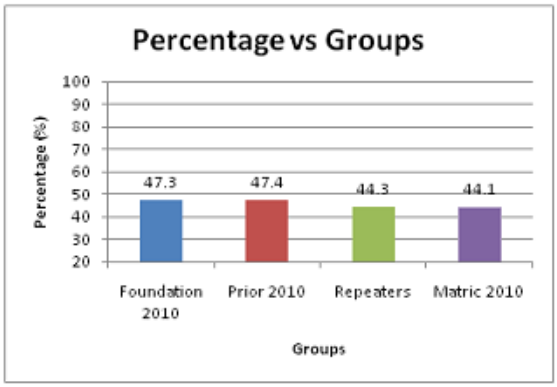

Figure 1: Percentages for groups

Table 1 summarizes the responses on multiple choice questions for each group.

Table 1: Students' response of question 1

Question 1	**Classification**	Matric 2010 **n=119** Response %	Prior 2010 **n=46** Response %	Foundation 2010 **n=42** Response %	Repeaters **n=27** Response %
1.1	Wrong	0	0	0	0
	Correct	100	100	100	100
	Not attempt	0	0	0	0
1.2	Wrong	5	0	4.8	0
	Correct	95	100	95.2	96.3
	Not attempt	0	0	0	3.7
1.3	Wrong	99.2	100	100	96.3
	Correct	0.84	0	0	3.7
	Not attempt	0	0	0	0
1.4	Wrong	32.8	43.5	71.4	44.4
	Correct	65.5	56.5	28.6	55.6
	Not attempt	1.7	0	0	0
1.5	Wrong	58	52.2	47.6	74.1
	Correct	40.3	45.6	47.6	25.9
	Not attempt	1.7	2.2	4.8	0
1.6	Wrong	12.6	8.7	14.3	7.4
	Correct	87.4	91.3	85.7	92.6
	Not attempt	0	0	0	0
1.7	Wrong	17.6	80.4	76.2	81.5
	Correct	81.5	19.6	21.4	14.8
	Not attempt	0.8	0	2.4	3.7
1.8	Wrong	91.6	91.3	100	92.6
	Correct	8.4	8.7	0	7.4
	Not attempt	0	0	0	0
1.9	Wrong	16.8	15.2	40.5	14.8
	Correct	83.2	84.8	59.5	85.2
	Not attempt	0	0	0	0
1.10	Wrong	31.1	34.8	61.9	74.1
	Correct	68.9	65.2	35.7	25.9
	Not attempt	0	0	2.4	0
1.11	Wrong	41.2	45.7	35.7	25.9
	Correct	58.8	50	64.3	74.1
	Not attempt	0	4.3	0	0

1.12	Wrong	8.4	12	7.1	3.7
	Correct	45	54.3	50	46.3
	Not attempt	47	33.7	43	50
1.13	Wrong	47.1	56.5	45.2	29.6
	Correct	52.9	43.5	54.8	66.7
	Not attempt	0	0	0	3.7
1.14	Wrong	68.1	52.2	50	51.9
	Correct	31.9	47.8	50	48.1
	Not attempt	0	0	0	0
1.15	Wrong	82.4	73.9	69	77.8
	Correct	17.6	26.1	31	18.5
	Not attempt	0	0	0	3.7
1.16	Wrong	64.7	54.3	59.5	40.7
	Correct	35.3	45.6	35.7	59.3
	Not attempt	0	0	4.8	0
1.17	Wrong	63.9	63	59.5	59.3
	Correct	36.1	37	40.5	40.7
	Not attempt	0	0	0	0
1.18	Wrong	41.2	23.9	52.4	44.4
	Correct	58.8	76.1	47.6	55.6
	Not attempt	0	0	0	0
1.19	Wrong	14.3	8.7	7.1	14.8
	Correct	85.7	91.3	90.5	85.2
	Not attempt	0	0	2.4	0
1.20	Wrong	31.9	26.1	57.1	37
	Correct	67.2	73.9	42.9	63
	Not attempt	0.8	0	0	0

The questions were classified as correct if the student got the correct answer, wrong if the student attempted the question but got it wrong and not attempted if the student left an empty space.Question 1.1 and question 1.2 from table 1 were asking for the definition of a scalar and a vector. It shows that all the groups managed to score very well on the definitions. The whole class were able to define a scalar irrespective of the group they are in.

For question 1.3, the correct answer was not among the given ones, meaning the answer was ***none of the above***. The two groups (foundation and the prior 2010) got it wrong. Only 3% of the repeaters managed to get it correct. This indicates that students do not work out the multiple choice questions; they just assume that the correct answer is there and they pick up anyone.

Questions 1.4 and 1.5 were asking about determining the resultant of two vectors. Above 70% of the foundation group got 1.4 wrong, while above 70% of the repeaters got 1.5 wrong. It indicates that there is a problem with the knowledge brought forward by the two groups who were exposed to the university physics before in determining the magnitude and direction of two vectors. The matric 2010 group was the highest in scoring question 1.5 with 58%.

Question 1.8 was a true or false statement asking them to choose the statement which is not true. More than 90% of the students got it wrong. Most of them chose the statement which is true. It indicates that students do not read questions carefully. Majority of the students from all the groups did not attempt question 1.12 in full.The question had more than one correct answer. Most of the students gave one answer instead of two, the reason might be students thought that multiple choice questions have only one correct answer.

Students were given different drawings in question 1.15, they had to interpret the drawing and give the corresponding correct drawing based on the statement given. 82% of the matric 2010 group got

it wrong. This question indicated that it is difficult for students to relate a statement to a drawing or to interpret the drawings. 69% of foundation group got it wrong. It indicates the difficulty of the question, because this group had the opportunity of going through foundation level. Similar trend was observed with repeaters, who studied vectors during their first attempt, only 33% got it correct. Question 2 was classification. Students' responses are shown in table 2 below.

Table 2: Students' response to question 2.

Question 2	**Classification**	**Matric 2010 n=119** Response %	**Prior 2010 n=46** Response %	**Foundation 2010 n=42** Response %	**Repeaters n=27** Response %
2.1	Wrong	27.7	21.7	33.3	25.9
	Correct	69.7	76.1	61.9	70.4
	Not attempt	2.5	2.2	4.8	3.7
2.2	Wrong	25.2	37	31	29.6
	Correct	71.4	60.9	64.3	66.7
	Not attempt	3.4	2.2	4.8	3.7
2.3	Wrong	17.6	30.4	19	22.2
	Correct	79.8	67.4	76.2	74
	Not attempt	2.5	2.2	4.8	3.7
2.4	Wrong	16	15.2	9.5	8.3
	Correct	81.5	82.6	85.7	88.9
	Not attempt	2.5	2.2	4.8	3.7
2.5	Wrong	30.3	15.2	35.7	11.1
	Correct	67.2	82.6	59.5	85.2
	Not attempt	2.5	2.2	4.8	3.7
2.6	Wrong	8.4	4.3	4.8	11.1
	Correct	89.1	93.5	90.5	85.2
	Not attempt	2.5	2.2	4.8	3.7
2.7	Wrong	30.3	30.4	38.1	37
	Correct	69.7	69.6	61.9	63
	Not attempt	0	0	0	0
2.8	Wrong	63	58.7	45.2	81.5
	Correct	36.1	41.3	52.3	18.5
	Not attempt	0.8	0	2.4	0
2.9	Wrong	61.3	63	42.9	63
	Correct	37.8	37	57.1	37
	Not attempt	0.8	0	0	0
2.10	Wrong	18.5	26.1	28.6	22.2
	Correct	81.5	73.9	71.4	77.7
	Not attempt	0	0	0	0

Questions 2.1 to 2.6 were quantities, from which students had to classify them as either a vector or a scalar, for example 10N. Most of the students got them correct. For questions 2.7 to 2.10, the questions were in a statement form. The students had to read the sentence and decide whether it is a scalar or a vector. Students scored low marks for questions 2.7 – 2.10 as compared to question 2.1 – 2.6. It means, it is difficult for students to read sentences and classify them as compared to classifying one word. Table 3 below shows the results of question 3. Question 3 was graph drawing based on calculations. Question 3 was rated 30 marks, and the number in the parentheses is the total mark for each section.

Table 3*: Students' response of question 3.*

Question 3 (30)	**Matric 2010 n=119**	**Prior 2010 n=46**	**Foundation 2010 n=42**	**Repeaters n=27**
3.1 (6)	0.5	0.8	2	1
3.2 (8)	1.1	1.4	1	1
3.3 (16)	3.2	3.8	5	3
Average	4.8 = **16%**	6 = **20%**	8 = **26.7%**	5 = **16.7%**

Foundation group was the highest in question 3.1 and 3.3 whereas the repeaters were the lowest in question 3.2 and 3.3. Question 3.1 students were expected to use parallelogram method, question 3.2 students were expected to resolve a vector in its components and calculate magnitude and direction, and question 3.3 students were expected to calculate the resultant of two vectors in vector component form and calculate its magnitude and finally represent them graphically. All groups scored below 30%, which indicates that students lack some knowledge, especially graphical representation of vectors.

4. Conclusion

This study showed that all students move to the next level with certain knowledge of vectors from the previous levels. There are some questions that students who passed their matric in 2010 performed better than those who went through foundation course and those who are repeating the same level. It can be concluded that high school physics gives some background on the topic. The prior 2010 group, are the students who were not studying during 2010 and they are not the product of OBE system. Their performance was good as compared to all the groups. It can be concluded that the education system plays a role in students' prior knowledge, since some concepts are not covered in the new system.

[5] and [4] have documented student difficulties with bothalgebraic and graphical aspects of vector concepts among students in introductory physics courses at several institutions. Those difficulties are similar to what we discovered in this study.Most students seem to lack a clear understanding of what is meant by vector direction. Many students are confused about the head-to-tail method and parallelogram addition rules.

This study recommends that, some instructional materials have to be developed and the amount of time given to vector concepts be increased because the vectors are a core of mechanics sections in introductory physics.

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