A critical assessment of first year entering university science students' conceptual understanding

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Abstract. Meaningful conceptual understanding is a key requirement for the acquisition of applied knowledge for the navigation of sophisticated studies in science and engineering. It is a known fact that the academic migration of students from the school sector to institutions of higher learning is essentially accompanied by the existence of conceptual knowledge gaps in various content domains. In response to this difficulty and as a critical component of the First-Time Entering Students' Orientation programme, a diagnostic questionnaire was administered to 222 first year science and engineering students at the University of Johannesburg prior to the commencement of the academic programme in order to establish the nature and extent, if any, of their conceptual knowledge gaps. In terms of its design, the diagnostic questionnaire encapsulated items based on various conceptual knowledge areas pertaining to Grade 8 to 12 Physical Science content domains. Analysis of students' responses revealed the existence of conceptual knowledge gaps which may impede meaningful learning.

1. Introduction

It has been observed that school leavers are inadequately prepared for higher education studies in science within the South African context due partly to lack of adequate mathematical skills (analytical, problem solving, manipulative, visualization and algebraic skills) and fundamental changes associated with curriculum reform as major impediments afflicting student learning [1]. In the main, curriculum reform in South Africa entailed phasing out the differentiated Higher Grade/Standard Grade system in all the learning domains and the inclusion of Mathematics Literacy as a viable alternative for learners not taking core Mathematics.

Local and international benchmark tests largely painted a gloomy picture about the quality of the South African education system. For instance, Grade 8 and 9 learners demonstrated dismally inadequate performance in mathematics and science [2]. This performance was commensurate with South Africa's global ranking in terms of the quality of mathematics and science education as well as the quality of the overall education system. South Africa was placed 143rd out of 144 countries surveyed during the 2012-2013 period and subsequently 148th out of 148 countries during the period 2013-2014 in terms of the quality of mathematics and science education [3,4].

Yet higher achievement levels are required for students to be admitted for higher studies in science. Results from the National Senior Certificate Examination written during 2013 indicated that a meagre 25.6% of the learners who passed were eligible to enrol for degree studies while 36.8% were eligible for diploma studies [5]. The breakdown in terms of the number of students eligible for higher studies during the period 2010-2013 is as follows [5]: 205 364 (2010), 180 585 (2011), 179 194 (2012) and 184 384 (2013). The breakdown itself presents a grim reality in relation to key aspirations pertaining to the attainment of meaningful human capital development within the broader South African context.

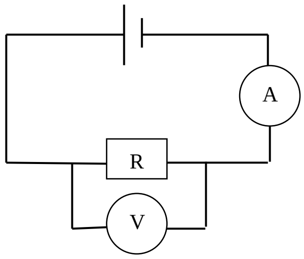
The prevailing articulation gap has a potentially detrimental impact on students' academic success at higher education institutions as a large majority of the students find it increasingly difficult to complete their studies in regulation time. Academic personnel are consequently grappling with various challenges such as large classes and cultural diversity coupled with serious knowledge gaps and conceptual inadequacies exhibited by the students. The conflation of various factors afflicting student academic performance prompted universities to introduce extended programmes underpinned by student-centred approaches making provision for remedial intervention and early identification of at risk students. It is against this background that this article provides a critical assessment of first year entering university science students' conceptual understanding.

2. Methodology

A questionnaire covering Physical Science topics from Grades 8 to 12 was administered to first year entering university students (*n = 222*) in Engineering, Optometry, Food Technology and Biotechnology. The topics covered ranged from general science in the General Education and Training (GET) Phase to Physical Science in the Further Education and Training (FET) Phase. More specifically, these topics included density, work, energy and electricity. Substantial effort was made to ensure adherence to the school syllabus. Suffice to indicate that the questionnaire itself was administered during the orientation week when students were formally introduced to the university setting. A summary of the type of questions, excluding the options (for most questions) and the relevant syllabus coverage is given in Table 1 below.

Table 1: Type of questions used

QUESTION	SYLLABUS IDENTIFICATION
1. A rectangular wooden block is 5 cm long, 3 cm high and 2.5 cm wide. The mass of the block is 26 g. Calculate the density of the wooden block.	Basic general science question from the grade 8 science syllabus.
2. "Frosted glass" is an example of A. Transparent material B. Translucent material C. Opaque material D. None of the above E. I cannot remember this one	A definition question from the grade 9 syllabus
3. Consider a closed circuit as shown below How will the voltmeter (V), ammeter (A) reading change if bulb of resistance R is burnt out during an experiment?	An electricity question from the grade 10 syllabus

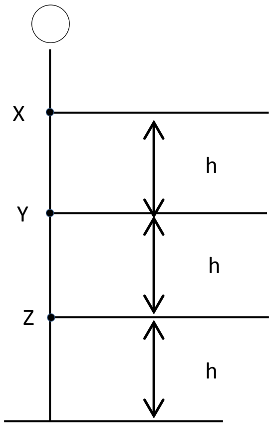


Options	Ammeter reading	Voltmeter reading
A	increases	Increases
B	Becomes 0	Becomes 0
C	Becomes 0	Does not change
D	Decreases	Becomes 0
E	Does not change	Decreases

4. A person stands on a bathroom scale which is placed inside a lift. When the lift is stationary, the reading on the scale is X newton's. What will be the reading on the scale if the lift is moving at constant velocity downwards?

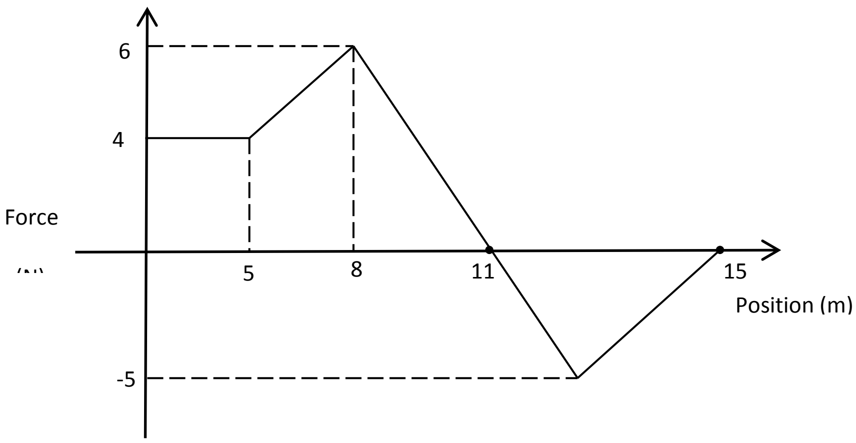
A grade 11 question on Mechanics

5. An object is in free fall. The picture below shows its motion. Find the ratio of the kinetic energy at point Z to the total mechanical energy of the object



A grade 11 question on Energy

6. A graph representing applied force versus position of an object is given below. Find the kinetic energy gained by the object as it travels a distance of 15 m.



A grade 12 question on Work and Energy

7. Lithium, beryllium and mercury have work functions of 3.68×10^{-19} J, 3.90×10^{-19} J and 4.5×10^{-19} J, respectively. Light with a wavelength of 400 nm is incident on each of these metals. Which one of these metals will exhibit photoelectric effect?	Grade 12 question on Photoelectric Effect

3. Findings

Table 2 below provides student performance across the seven questions which formed an integral part of the questionnaire administered.

Table 2: Summary of performance

QUESTION NUMBER	GRADE	CORRECT OPTIONS
1	8	35%
2	9	26%
3	10	15%
4	11	45%
5	11/12	21%
6	11/12	11%
7	11/12	16%

Question 1 involved the calculation of volume as one of the essential concepts in science. Students' performance on Question 1 (35%) suggests lack of understanding of basic concepts in Physics. Question 2 primarily focused on the recall of basic laws, principles and definitions taught in the earlier grades. Students' performance on Question 2 presents a grim reality in terms of their understanding of electrical circuits. In fact, it has been observed that learners have consistently demonstrated inadequate performance on questions involving electrical circuits in the Senior Certificate Examination [4]. Considerable amount of time appears to be devoted to the teaching of mechanics at school as the performance on Question 4 seems to suggest. Question 5 involved the determination of work done based on a graphical representation. Graphical interpretation further appeared to be a critical challenge for the students as the performance on Question 5 (21%) indicates. Question 6 involved the application of the principle of conservation of energy and the performance in this regard (11%) leaves much to be desired. As the performance on Question 7 (16%) illustrates, students appeared to confuse work function of a metal and the associated threshold frequency. In addition, this performance points to insufficient meaningful coverage of the photoelectric effect as a crucially important concept in Physics. A summary of the performance of top students is given in Table 3 below.

Table 3: Summary of the performance of the top students

QUESTION NUMBER	GRADE LEVEL OF THE QUESTION	CORRECT OPTIONS SELECTED (%)
1	8	55%
2	9	27%
3	10	27%

4	11	27%
5	11/12	36%
6	11/12	18%
7	11/12	18%

Some of the items in the questionnaire probed the availability of laboratory facilities and the concomitant provision of adequate practical exposure at schools. A vast majority of the students indicated that laboratory facilities were nonexistent at their schools resulting in limited opportunities for practical exposure. In essence, lack of adequate practical exposure and inadequately developed conceptual understanding appear to be the root causes of pronounced knowledge gaps and conceptual inadequacies within the context of this inquiry.

4. Recommendations

South Africa is duty bound to provide a globally competitive curriculum that responds to the economic and societal needs of the country. In terms of curriculum reform, there is a critical need for Physics and Chemistry to be treated as two separate entities in order to provide meaningful opportunities to assess learner performance in these content domains. Particular emphasis has to be put on the development of pedagogically valid instructional approaches that serve to enhance meaningful conceptual understanding coupled with a coherent infusion of appropriate practical activities. However, these ideals cannot be brought to full fruition without the provision of concrete and relevant teacher professional development opportunities within firmly established communities of practice.

5. Conclusion

Inadequate mathematical skills can be a major impediment to meaningful learning of science at institutions of higher learning. Within the context of this inquiry, students demonstrated knowledge gaps and conceptual inadequacies which may potentially serve as conceptual hurdles to be overcome in order to make appropriate progress in their studies. Institutions of higher learning are faced with an added imperative to put systems in place that adequately respond to the critical needs of students in order to give practical expression to human capital development priorities.

References

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