UNDER PREPAREDNESS OF FIRST YEAR UNIVERSITY MATHEMATICS STUDENTS

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Abstract–First year entering university students bring with them low levels of mathematical understanding and abilities. There is insurmountable evidence that points to the fact that the new mathematics curriculum is failing our students in many ways. This lack of limited repertoire of basic mathematical skills stems from a dysfunctional schooling system brought about by the exclusion of crucial topics such as geometry, trigonometry and logarithms. This has serious rippling effect for students wishing to pursue studies in the exact sciences, where problem solving, analytic and abstract thinking is the order of the day. The aim of this study is to determine to what extent the students' lack of basic mathematical skills is hampering their progression to higher study both at high school and beyond.

Keywords: curriculum reform, dysfunctional schooling, analytical skills, cognitive development and under-preparedness

1. INTRODUCTION

Research conducted by the South African Institute of Physics (SAIP) and the Council for Higher Education (CHE) (Nkosi, 2013) in some 20 South African universities revealed with great unanimity that the "school mathematics is failing varsity entrants". In particular the report points towards the under-preparedness that has engulfed the schooling sector over the past 5 years stemming from the curriculum reform that has taken place, leaving students with a lack of adequate mathematical and necessary problem solving skills in the gateway subject required for university entrance. Under-preparedness manifests itself in many ways; from "what students know and can do" (Scott, 2013) to the lack of deep conceptual and theoretical knowledge, to the "lack of fundamental ability" or a lack of "cognitive deficit" that is a prerequisite for students to bridge the gap between the exit of the secondary school sector and tertiary education. On the other hand, Higher Education curriculum which is variant for international acclaim, assumes that the baseline knowledge to be in place so that lecturers may proceed to the next level of understanding. Over the years there has been a decline in the "average-level of student preparedness" (Scott, 2013) for tertiary entrance and this has serious repercussions for South Africa as a whole where a technology driven economy is the order of the day for the 21st century competencies.

Data so far may indicate that the current situation may be worsening. There is growing evidence that suggests that the curriculum reform by the introduction of the new secondary curriculum and the National Senior Certificate (NSC) which was introduced in 2008, have led to lower levels of performance of first year entering students in university subjects such as mathematics, science, engineering and technology related subjects (Scott, 2006; Scott, 2011; Fisher, 2011). The "challenge level" of the matric examination paper together with the omission of key topics in the secondary syllabus which are pivotal for higher order studies and very predictable nature of the examination indicate a decline in the worthiness of the gateway subjects such as mathematics and physical science.

The problems that students face at the exit of their senior secondary phase all point towards a "deep-seated failings throughout the school system" (Fisher, 2011). This is indicative of the little progress that is made towards the development of cognitive level among South African youth. Local and international assessments reveal that South Africans students are performing consistently

poorly in numeracy, reading, literacy, mathematics and science. Some of the assessments that testify to these assertions are from the following bodies:

1.1 South African Democratic Teachers' Union (SADTU)

According to an independent research conducted by SADTU, the new curriculum reform has had two casualties, namely the teacher and the student. On one hand, the "students' level of competency has dropped" and on the other hand the teachers have struggled to come to terms with the offerings of the new curriculum (Nkosi, 2013). If the teacher is struggling then there is a serious problem with the state of education in South Africa since they are supposed to be the embodiment of knowledge and a caveat for systemic change is necessary.

1.2 Annual National Assessments (ANAS)

The ANAS which assesses numeracy and literacy reveal low levels of achievement in the "fundamental building blocks of learning" (ANAS, 2011). In ANAS's assessment in 2012, the grade 9 learners obtained a mere 13% in the mathematics assessment tests confirming the low level achievement. The grade 6 learners have performed equally badly with achievements of 30% and 27% for the years 2011 and 2012, respectively (ANAS, 2012). To remedy the situation at any level workbooks have been issued by DOE to standardise the level of learning and teaching in schools.

1.3 Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ)

Research undertaken by SACMEQ in 2011 revealed that only 46% of grade 6 mathematics teachers were able to get an average grade 6 multiple choice question correct (Spaull, 2013) South African mathematics teachers fared badly to comparator teachers in Africa. The grade 6 learners themselves also performed badly. According to SACMEQ 83% of South African grade 6 and 8 learners did not reach the competence of their level. In particular 52% of grade 6 learners achieved mathematics scores at the level of a grade 3 learner or lower (GDE, 2010). An international report on the African consortium revealed that "only 32% of grade 6 mathematics teachers in South Africa had desirable subject knowledge". Teachers definitely need to have a thorough mastery of mathematics many grades beyond their present grade of teaching in order to have the confidence in the subjects they teach, otherwise schools will become "academically bankrupt" with levels of learning and teaching in mathematics reduced to a minimum (Spaull, 2013).

1.4 Third International Mathematics and Science Study-Repeat (TIMSS-R)

Results from TIMSS showed that 27% of South African teachers did not have any formal training in the mathematics (Howie, 2006). This is very disturbing as many teacher colleges have been shut down for no apparent reason. Further from the international assessment of TIMSS for mathematics and science, South Africa was ranked 137 out of 150 countries for numeracy and literacy (SABC news 2011). This is disappointing as comparator countries with less resource have performed better (TIMSS, 2003). In 2003 TIMSS study revealed a pass rate of 33% for grade 8 learners in mathematics (GDE, 2010). The study is of the opinion that the South African learners were the worst performers compared to other countries.

1.5 Department of Education-Mathematics results

A survey of the NSC mathematics examinations results from 2011 to 2013 is shown in the table below (DBE, 2013):

	10-19.9%	19.9-29.9%	30-39.9%	40-49.95	50-59.95	60-69.9%	70-79.9%	80-89.9	90-100%
2011	9.5	23.1	20	11.6	7.6	5.1	3.4	1.9	0.6
2012	8.3	18.8	18.9	13.0	9.2	6.4	4.1	2.2	0.7
2013	7.1	16.2	18.6	14.3	10.5	7.4	4.8	2.6	0.8

For a student to be accepted in the exact sciences, a pass of 60% in mathematics is a minimum requirement. This means that 11% (2011), 13% (2012) and 15.6% (2013) of the total cohort of

students would be eligible for university admission. A pass of 30% in mathematics is undesirable. If the pass rate had to be raised to 50%, the real pass rate in mathematics would be 23.1%, 22.1 and 26.1% for the 3 years respectively. Many diploma courses require a pass of 50% or more. Many schools are "gaming" the system by allowing many students to do Mathematics Literacy to produce good pass rates so that the school may look good in the region. The number of students that are doing Mathematics Literacy is increasing at a more or less steady rate: 280 836 (2010), 275380 (2011), 290713 (2012) and 324097 (2013). The mathematics enrolment rates show a steady decline: 263034 (2010), 224635 (2011), 225874 (2012) and 241509 (2013). These numbers are too low for enrolment in Science and Technology subjects, where the average has been less than 30% from 2000 to 2010 (Bunting, 2010). The department has set this target as 30% for 2010 and above.

1.6 Enrolment and pass rates at University

Of the students that wrote the NSE examination in 2012, 136 000 of them obtained Bachelor passes, while 120 000 of these students enrolled for extended programmes (CHE, 2013). This means that their grades were not good for main stream courses and they are offered a second chance to improve their grades, with an extended duration of a degree or diploma programme. On the other hand, a staggering 153 000 students obtained diploma passes, meaning that these students will not be able to register for a degree course and will have to repeat some of their courses to improve their grades. For a 3 year degree qualification, only 16% of the registered cohort of students was able to finish in regulated time, and for a diploma the graduation rate is 33% (CHET). The attrition rate after first year of study is 56% and 46% for the degree and diploma studies, respectively. Based on the empirical data collected and analysed roughly 20% of all students that applied for tertiary studies were accepted in 2010 (SARU, 2012).

The response of universities to a failing school system is two-fold, namely a deviation of traditional-type of lecturing and by the introduction of foundation (bridging) or extended programmes. The purpose of these programmes is to improve the content knowledge that was assumed to be in place. Due to the large influx of incoming students with a wide diversity of cultures, it is imperative to know their content knowledge that they bring with them which is the primary purpose of this study.

2. METHODOLOGY

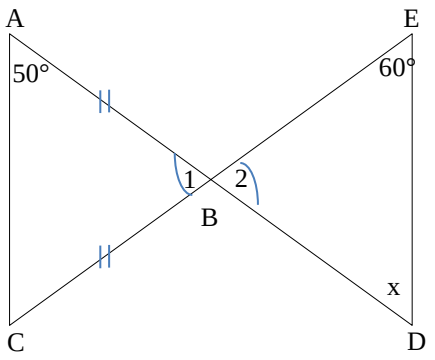
A questionnaire in the form of a quiz which covered topics in mathematics from grade 8 to 12 was done in consultation with a senior member of the secondary teaching fraternity and was subsequently given to senior members of the Mathematics department of the University of Johannesburg for comments and feedback. The topics covered ranged from the senior primary phase to the senior secondary phase of high school. To test the students' mathematical skills and abilities, a broad scope of topics such as elementary geometry, word problems, calculus, algebraic equations and inequalities were assessed. It was expected that the questions set in the questionnaire was firstly, in line with the syllabus coverage and secondly, that the questions set was of a level of manageability of the student. Concomitant with the quiz, the students grade 12 Mathematics, Science and English marks were captured to ascertain if there was any correlation in performance and if they were capable of tertiary study.

3. SURVEY, DATA COLLECTION AND RESULTS ANALYSIS

During First Year Students' orientation week at University of Johannesburg (UJ) in January 2014, students were asked to complete the following quiz without any prior notice or preparation. It was of approximately 30 minute duration and consisted of 6 baseline questions which were validated by Senior Members of the Mathematics Department at UJ. They were asked to do the workings along the side of the questions, but were only required to tick off one of the options provided. Some of the answers options were: "Never seen this question before", "I cannot work it out". These options were given if the students were uncomfortable with the options provided. The use of the calculator was optional. The purpose of word problems was to test problem solving skills. A one page quiz was administered to first year entering university students (n = 203) in the fields of Engineering,

Optometry, Chemical Engineering, Food Technology and Biotechnology. A summary of the quiz type and syllabus coverage is given in Table 1 below.

Table 1

QUESTION	SYLLABUS IDENTIFICATION
1. 	Basic geometric questions from the 8 mathematics syllabus
2. Half of a certain number plus one third of the same number is 14 less than twice the number. Find the number.	Word problem on the algebraic section of the grade 9 syllabus.
3. Solve for x: $\frac{1}{x}-\frac{1}{m}=\frac{t}{n}$	A question on basic algebraic manipulations of the grade 10 syllabus
4. Find the sum of all integers satisfying $x^2 - x < 20$	An inequality question from the grade 11 syllabus
5. A bell-ringer rings a church bell once every hour at 1 o'clock, twice at 2 o'clock, 3 times at 3 o'clock and so on, going up to 12 times at 12 o'clock. How many times does he/she ring the bell over a period of 24 hours?	Word problem testing the section sequences and series of the grade 12 syllabus
6. Given $y=\frac{x^3-x}{x-1}$. Find $\frac{dy}{dx}$	A calculus question of the grade 12 syllabus

Cumulative results from the performance of the students in the various fields of study is given in Table 2 below

Table 2

QUESTION NUMBER	GRADE	CORRECT OPTION
1	8	37%
2	9	55%
3	10	65%
4	11	52%
5	12	52%
6	12	33%

Most students performed badly in the grade 8 geometry question and this highlights the plight that geometry was taken out of the core mathematics syllabus and offered as an optional subject as Mathematics Paper 3, and in essence done by roughly 5% of the entire cohort of students. Although the students have just passed their grade 12 examinations, it appears their geometrical foundations

are very shallow and this will have serious impact on their analytical and visualisation skills. Their performances in the grade 9 question was very average and this concurs with the national findings of the Annual National Assessment mathematics test for which the students only obtained an average of 14% in the 2013 assessments and 13% in the 2012 assessments. Also to be mentioned that only 3% of the students had obtained more than 50% for the Mathematics examination. A number of factors could be associated with this lack of basic skills and knowledge, and this could be teacher competency and whether teachers have the necessary skills and resources to teach the students under their care. Thus the inherent gaps that are associated with this lack of content knowledge in the transitional grade 9 year are carried over from year to year until they enrol for tertiary studies. The calculus question in grade 12 which was done a few months prior to this quiz leaves much to be desired. Most students choose a similar wrong option which reveals a lack of deep understanding and poor teaching of the concept. Calculus forms the basis of understanding of all tertiary mathematical and related studies, leaving these students grossly ill prepared for higher studies. Students performed reasonably well in the grade 10 algebraic question. The grade 11 question on inequality was also poorly answered. All this suggests that students are not studying with a deep sense of understanding. Teachers maybe rushing these sections in school to complete the syllabus thereby meeting the deadline of writing a common departmental paper. Roughly 45% of the student of the entire cohort of students abandon their studies between grades 10 and 12, which is a crisis in education of monumental proportion.

On the other hand if the performance of the students in the quiz is narrowed down only to those that obtained 80% or higher in their grade 12 mathematics examination, the results are quite alarming for the status of mathematics in South Africa. Of the cohort of 203 students that attempted this test, 19 of them revealed that they had obtained 80% and over in their matric mathematics paper. A summary of their performance is given in Table 2 below.

Table 2

QUESTION NUMBER	GRADE	CORRECT OPTION
1	8	68%
2	9	53%
3	10	79%
4	11	79%
5	12	53%
6	12	58%

If the students did not have any clue as to how to do a question or if they were not confident about answering a question, fearing of getting it wrong, they simply answered “I cannot work it out” or “Never seen such a problem before”. The word problems seems to be the most problematic for students to answer. The results of which are shown in table 3.

Table 3

QUESTION	I cannot work it out	Never seen such a problem before
1	1.5%	1%
2	11%	5%
3	9%	2.5%
4	7%	3.5%
5	11%	3%
6	2%	1%

These results points to the fact that the students are struggling with word problems in general. These students will struggle with tertiary work where a high level of analytical thinking and abstract

work will be the order of the day. It is inconceivable that only 68% of these students got an elementary grade 8 geometry question correct. More shockingly, the section on sequences and series in grade 11 in the form of a word problem as well as a simple word problem in grade 9 reveals a poor level of cognitive development in their mathematical understanding. Therefore the reasonably good grade 12 results implicate that there might be a possibility that the students are 'spotting' examination type questions in their preparation or their marks could be moderated to produce a desired grade 12 pass rate. According to the moderator's report from the markers of the Senior Certificate in 2013, "students struggle with Mathematics in Grades 11 and 12 because they cannot do the basic mathematics of grades 8, 9 and 10" (DOE, 2013). This was in reference to questions on inequality. Comments on the calculus section point to shallow teaching of the section in school. A further comment made by them on geometry, for those that wrote the Mathematics Paper 3, students are making many errors in the paper due to a "poor understanding of the basics and foundational competencies taught in the earlier grades". Thus the understanding of concepts in the curriculum is due to a lack of deep conceptual understanding and the ability to answer questions that require a higher order of thinking.

4. CONCLUSION

Students have had the most difficulty with the section of calculus which is pivotal to the understanding of tertiary mathematics. Hence the presumption of conceptual understanding that is supposed to be in place should not be taken for granted and a baseline test needs to be in place before any form of lecturing is done (Jennings, 2009). Students appear to have forgotten the fundamental concepts in mathematics in the different phases of their study and have been promoted to higher grades without a sound and solid foundation of their previous grades, bearing in mind that they need between 30-40% to progress to the next grade. The idea of using the National Benchmark Test (NBT) as a criterion for admission to universities is much debated in South Africa, as there appears to be no correlation between the NSC matric results and the NBT tests. However, students might have performed better if they were given sufficient warning and more time for the tests. It might be interesting to see how the students would perform if the same test was given to the students after a semester of study as a follow-up test.

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