Success in first-year mathematics: School-leaving examinations and first-year performance

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Studying towards a BSc degree at universities in South Africa requires at least one course in mathematics. A course in mathematics also is a prerequisite if a candidate wants to register as a professional scientist with the South African Council for Natural Scientific Professions.[1] Programmes in actuarial science, engineering and mathematics itself require more than one year of university mathematics, whereas other BSc programmes typically require mathematics in the first-year curriculum only.

Entrance to study a BSc at South African universities is based on a prospective student's level of performance in the final school leaving – Senior Certificate (SC) or National Senior Certificate (NSC) – examination. At the University of the Free State (UFS), the mathematics entrance requirement for the BSc in Actuarial Science and the pure mathematics and applied mathematics programmes is a higher-grade B (HG B) symbol in SC school mathematics or a level 6 for mathematics in the final NSC examination. Other BSc programmes require a minimum of a standard-grade C (SG C) in SC school mathematics or a level 4 for mathematics in the final NSC examination.

In 2008, the first cohort of matriculants completed the new NSC curriculum. An analysis of the mathematics examination results indicates that the number of learners that obtained a mark of 80% and higher in school mathematics increased significantly.[2] A disproportionate number of students achieved high mathematics symbols, and consequently significantly more students achieved the minimum entrance requirements and were accepted into engineering and science faculties nationwide in 2009.[3] For example, 30% more students entered the Faculty of Engineering and the Built Environment, and 8% more entered the Faculty of Science at the University of Cape Town in 2009.[3,4]

During February 2009, the 2009 cohort entering the UFS undertook a battery of Alternative Admissions Research Project (AARP) tests.[5] Students entering the Faculty of Natural and Agricultural Sciences wrote a mathematics comprehension test and a mathematics achievement test. In the mathematics comprehension test the students achieved an overall average score of 44%. The students performed well in the basic mathematics cluster with an average of 83%, but achieved low average scores in the analysis cluster (34%) and the synthesis cluster (2%). In the mathematics achievement test, the students achieved an overall average score of 37%. The average in all clusters of this test was below 40%. According to the AARP Centre, this result is an indication that the majority of these students would find it difficult to pass mathematics at university level without additional support.

The National Benchmark Test Project (NBT), piloted in February 2009 with the 2009 cohort of higher education entrants at selected institutions, was implemented in August 2009 for the 2010 entrants. The results of the tests are divided into four proficiency levels[6]: proficient (62% – 100%), upper intermediate (49% – 61%), lower intermediate (34% – 48%) and basic (0% – 33%). The results of the pilot study indicated that of the students who wrote the NBT mathematics, 6% achieved the proficient level, 73% achieved an intermediate level and 21% achieved the basic level.[7,8] The 2010 NBT report[6] indicates that 8% of the cohort achieved the proficient level, 21% achieved the upper intermediate level, 36% the lower intermediate level and 35% the basic level. These results indicate that 92% of the students who applied for entry into universities in 2010 would need some form of mathematics support[6]; these findings are similar to those of the AARP project mentioned above.

Several media reports have expressed the view that learners had been poorly prepared at school level. Serrau[9] suggested that weakness in the 2008 school mathematics was directly responsible for the poor performance of first-year students in first-year university mathematics courses. Blaine[10] has claimed that the new school mathematics curriculum does not give learners enough grounding for programmes such as engineering and mathematics itself. The performance in 2009 of first-year engineering students, who moved directly from school to university, showed a marked decline in first-year mathematics compared to the 2008 cohort.

At the UFS we use a pre-calculus test for first-time entrants into first-year mathematics to establish their competency in mathematics, primarily to offer curriculum advice. The pre-calculus

test has been taken by all students entering the Faculty of Natural and Agricultural Sciences since 2004. Table 1 shows a comparison of the symbols of first-time entrants from the old SC final examinations (between 2004 and 2008), their performance in the pre-calculus test, and their final results in the mathematics modules WTW 114 (major module) or WTW 134 (service module). When universities calculate an M-score for entrance purposes to universities, it is generally accepted that a SG A symbol is equivalent to a HG C symbol. However, our observations in terms of the pre-calculus test clearly show a significantly larger difference in student proficiency between these two symbols, namely that the SG A symbol instead corresponds to a HG E symbol.

The main aim in applying the pre-calculus test since 2004 has been the benchmarking of the SC mathematics symbol against the NSC performance level. Table 1 shows that SC learners with a HG A symbol obtained an average of 84% in the pre-calculus test. According to Table 2, NSC learners with a performance level 8 (90% – 100%) obtained an average of 82% in the pre-calculus test. From this we conclude that a level 8 symbol corresponds well to a HG A for school mathematics. Similarly, we can argue that performance level 7 (80% – 89%) and level 6 (70% – 79%) correspond to HG C (60% – 69%) and HG D (50% – 59%) symbols, respectively. Table 2 also shows that performance level 5 (60% – 69%) and level 4 (50% – 59%) correspond to SG B and SG C symbols, respectively, which indicates a difference of approximately 20%. Our results confirm the finding that NSC mathematics may be inflated by 20% in the lower ranges.[11]

The only NBT results available are those of the 2010 cohort. Table 2 shows the NBT results and their corresponding pre-calculus results. Students in the proficient level (≥62%) in the NBT, obtained a higher mark in the pre-calculus test, while students in the intermediate and basic levels of the NBT, obtained a similar mark in the pre-calculus test.

An important factor to consider is, however, the entrance requirement with respect to mathematics for study at a higher education institution and, with that, the success rate in mathematics in the first year of study. At the UFS, two mathematics modules are presented in the first semester of the first year: WTW 114 and WTW 134. WTW 114 is the module which leads to majoring in mathematics and actuarial science and in some programmes in physics and chemistry. This module is also the one which other universities recognise for engineering study. WTW 134 is a 'service' module, which is mainly for biological, earth and agricultural science programmes where mathematics is required only in the first year of the programme.

At the UFS, until 2008, the entrance requirement for WTW 114, the higher level mathematics, was a HG D symbol in the SC mathematics final examination. Since 2009, the requirement has been set as a level 6 in NSC mathematics. The data in Tables 1 and 2 clearly indicate that a HG D and a level 6 school mathematics proficiency is not sufficient to achieve success in the WTW 114 mathematics module. The entrance requirement for WTW 134, the 'service' module, was a SG C and a level 4 school mathematics proficiency. This entrance requirement leads to a success rate in this module considerably below 50%. We therefore conclude that standard-grade mathematics in the SC and a level 4 performance in NSC mathematics are not sufficient for success in our WTW 134 mathematics module.

One of the objectives of the NBT project is to assess the relationship between higher-education entry-level requirements and school-level exit outcomes.[7] The NBT reports show a dismal picture regarding the mathematics proficiency of the pilot cohort[7] in 2009 as well as that of the 2010 cohort.[6] Table 3 and Figure 1 indicate the success rates in the two first-semester mathematics modules, WTW 114 and WTW 134, at the UFS compared to the NBT scores. Our

TABLE 1: Performance in the pre-calculus test and in first-year mathematics modules WTW 134 and WTW 114 compared to Senior Certificate mathematics symbols of students in the 2004–2008 first-year cohorts in the Faculty of Natural and Agricultural Sciences at the University of the Free State.

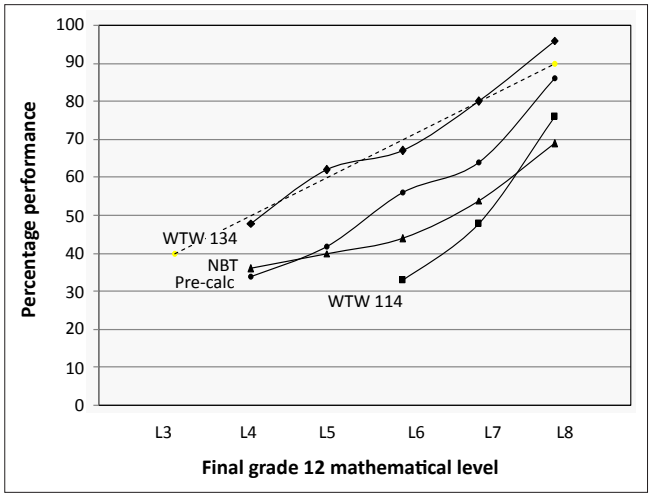
School symbol	Pre-calculus test		WTW 134			WTW 114		
	Average (%)	Standard deviation	Average (%)	Standard deviation	Pass rate (%)	Average (%)	Standard deviation	Pass rate (%)
Higher grade								
A	84	10	84	12	96	68	17	80
B	75	10	74	13	93	52	17	56
C	65	12	67	14	88	41	16	40
D	56	12	58	16	71	27	15	12
E	47	10	49	14	48	–	–	–
Standard grade								
A	49	11	53	16	64	23	15	8
B	38	10	42	16	36	–	–	–
C	31	10	38	18	30	–	–	–

TABLE 2: Performance in the National Benchmark Test (2010 cohort only), the pre-calculus test, and first-year mathematics modules WTW 134 and WTW 114 compared to National Senior Certificate mathematics level of students in the 2009 and 2010 cohorts in the Faculty of Natural and Agricultural Sciences at the University of the Free State.

School proficiency	National Benchmark Test result		Pre-calculus test		WTW 134			WTW 114		
	Average %	Standard deviation	Average %	Standard deviation	Average %	Standard deviation	Pass rate %	Average %	Standard deviation	Pass rate %
Level 8	69	8	82	11	89	8	100	72	13	85
Level 7	54	7	64	12	75	13	96	48	13	35
Level 6	44	7	52	12	63	13	81	26	14	12
Level 5	40	6	40	12	56	12	57	–	–	–
Level 4	36	6	33	10	46	12	38	–	–	–

TABLE 3: Performance in the pre-calculus test and in first-year mathematics modules WTW 134 and WTW 114 compared to National Benchmark Test results of the students in the 2010 cohort in the Faculty of Natural and Agricultural Sciences at the University of the Free State.

National Benchmark Test result Interval (%)	Pre-calculus test result		WTW 134			WTW 114		
	Average (%)	Standard deviation	Average (%)	Standard deviation	Pass rate (%)	Average (%)	Standard deviation	Pass rate (%)
80 – 100	–	–	–	–	–	–	–	–
70 – 79	90	5	100	0	100	71	13	100
60 – 69	77	10	79	12	81	64	11	92
50 – 59	60	10	70	12	90	39	16	30
40 – 49	46	13	61	14	74	40	14	26
30 – 39	39	10	57	12	70	–	–	–
20 – 29	28	7	54	13	62	–	–	–



Note: The dotted line is the proficiency level score at school.

FIGURE 1: Performance of the 2009 and 2010 cohorts of the Faculty of Natural and Agricultural Sciences at the University of the Free State in the National Benchmark Test (NBT), the pre-calculus test (Pre-Calc) and first-year mathematics modules (WTW 134 and WTW 114) compared to their final matriculation mathematics level (L3–L8).

data reveal a more positive picture than the NBT reports for success in first-year mathematics. That is, to be successful in WTW 114, a student should score at the proficient level in mathematics in the NBT, but a basic level for mathematics in the NBT is sufficient to be successful in the WTW 134 module.

The claim of the 2010 NBT report[6] that 92% of students with NSC mathematics entering higher education would need some form of mathematics support is only partly correct, at least at the UFS. Here, the claim is valid in terms of the mathematics required for programmes in actuarial science and mathematics itself, but not for programmes in the biological, earth and agricultural sciences, where NSC mathematics does adequately prepare students to pass the mathematics courses required.

A new school curriculum dictated by the 'Curriculum and Assessment Policy Statements (CAPS)'[12] has been implemented from 2012. The grade 12 learners of 2014 will be the first cohort to complete this curriculum. However, no major changes have been made to the mathematics content. The performance reporting (proficiency levels 1 to 7) will be similar to that of the current curriculum. Consequently, changes in mathematics entrance requirements at universities are unlikely to apply to the 2014 grade 12 cohort.

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