Broadening Epistemological Access to Tertiary Mathematics: challenges and opportunities

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Abstract

Higher Educations ability to retain and graduate students in the Science, Technology and Mathematics (STEM) disciplines is an international challenge, so too in South Africa where only 27% of students complete their studies in minimum time and where 55% will never graduate. This has raised the question of the difference between formal and epistemological access and the challenges of viewing access differently. These challenges have meant that extended degree programmes, where degrees and courses are formally done over a longer period of time (providing epistemological access), have become a feature of South African education. One challenge is determining which students will benefit from an extended programme or course and which will cope with the programme or course of study in minimum time. In South Africa there are two assessments of school-leavers that are pertinent to this debate. The first is the national school leaving examination, which is a statuary requirement for entry into higher education, and the second is the National Benchmark Tests. The first set of assessments comprises norm-referenced tests, which are therefore often difficult to interpret for the purposes of placement. The second set of tests comprises criterion-referenced tests, which are therefore better suited for this purpose. This paper describes the two assessments, tracks the academic standing of a cohort of students over six years and argues that using the results of the two assessments in a complimentary way is the most productive approach for the purpose of placement.

Proceedings of the Southern Africa Mathematical Sciences Association (SAMSA2016), Annual Conference, 21 - 24 November 2016, University of Pretoria, South Africa

http://samsa-math.org/

Conference Proceedings Paper

Broadening *Epistemological* Access to Tertiary Mathematics: challenges and opportunities

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Editors: Farai Nyabadza, Sandile Motsa, Simon Mukwembi and Michael Chapwanya
Received: 16 November 2016; Accepted: 20 December 2016; Published: 11 January 2017

Abstract: Higher Education's ability to retain and graduate students in the Science, Technology and Mathematics (STEM) disciplines is an international challenge, so too in South Africa where only 27% of students complete their studies in minimum time and where 55% will never graduate. This has raised the question of the difference between 'formal' and 'epistemological' access and the challenges of viewing access differently. These challenges have meant that extended degree programmes, where degrees and courses are formally done over a longer period of time (providing epistemological access), have become a feature of South African education. One challenge is determining which students will benefit from an extended programme or course and which will cope with the programme or course of study in minimum time. In South Africa there are two assessments of school-leavers that are pertinent to this debate. The first is the national school leaving examination, which is a statuary requirement for entry into higher education, and the second is the National Benchmark Tests. The first set of assessments comprises norm-referenced tests, which are therefore often difficult to interpret for the purposes of placement. The second set of tests comprises criterion-referenced tests, which are therefore better suited for this purpose. This paper describes the two assessments, tracks the academic standing of a cohort of students over six years and argues that using the results of the two assessments in a complimentary way is the most productive approach for the purpose of placement.

Keywords: norm-referenced assessments; crtierion-referenced assessments; placement; access.

MSC: Subject classification

1. Introduction

Most higher education systems struggle with the challenges of low throughput rates and high dropout rates. Among the 18 Organisation for Economic Co-operation and Development (OECD) countries for which data were available in 2010, some 31% of students who enter higher education fail to graduate. Graduation rates differ widely by country with some (Mexico, New Zealand, Sweden and the United States) having more than 40% of their higher education students not graduating, whereas for others (Belgium (Fl), Denmark, France, Japan, Korea, Spain and the Russian Federation) fewer than 25% of the students do not graduate [25].

For South African higher education only 27% graduate in minimum time. The majority of students take up to two years more than the minimum time for their degree studies and 55% of them never graduate ([29], [12]). These low throughput rates and high dropout rates exacerbate the problem of students taking longer than the minimum time. Extended degree programmes structure

their curricula in such a manner that students can typically do their degree studies over the minimum time plus one year. A difficulty is how best to determine which students would benefit most from an extended degree programme and which students would most likely cope with doing the degree in minimum time. In South Africa there are two assessments of school-leavers that are pertinent to this debate. The first is the national school leaving examination, the National Senior Certificate (NSC), which is a statutory requirement for entry into higher education. The results of the NSC are often difficult to interpret for the purposes of admission and placement. The second assessment is the set of tests provided by the National Benchmark Tests Project (NBTP) [21]. Two of the NBTP objectives are a) to provide a service to higher education institutions requiring additional information to assist in admission (selection and placement) of students in appropriate curricular routes and b) to assist with curriculum development, particularly in relation to foundation and augmented courses [21]. The National Benchmark Tests (NBTs) through their conceptualisation, design and implementation are particularly well placed to provide information for the purpose of placement. It is not only the content that is taught in the National Curriculum Statement (the school curriculum) that is essential for performing well in South African higher education. Even more important are the cognitive abilities and skills underlying the school curriculum content domains that are learned in one context and are believed to be transferable to another. The NBTs therefore focus on the application of knowledge obtained in the school context to the higher education context. The NBTs are thus designed to provide the kind of information which the South African higher education sector requires in order to make decisions about the most appropriate curriculum structures for students.

This paper argues that ranking applicants for selection is important, but there are two even more important considerations when making selection decisions. The one is placing students in appropriate curriculum structures and the second is that the curriculum structures themselves should take into account what students can and cannot do. Without mechanisms for appropriately placing students and identifying how the curricula should respond to the students who are admitted, the South African higher education sector is likely to continue to fail students. We argue that the extended degree programmes, which serve approximately fifteen percent of the first year higher education population, should become the norm, and what are often referred to as the regular or mainstream programmes should progressively become the exception. We use information about the two national assessments to argue that information gained through the criterion-referenced NBTs could fruitfully complement the NSC norm-referenced assessment to address the main challenge for South African higher education, which is to find a credible and valid mechanism for placing students in the two curriculum routes. The paper then goes on to investigate the performance information of prospective 2016 South African higher education students on the NSC and NBTs to show the relationship between these two assessments.

2. The South African higher education context

2.1. Racialised patterns of performance

South African higher education is marked by low graduation rates and high levels of failure and dropout. These continue to affect the historical apartheid 'African', 'Coloured' and 'Indian' racial groupings the most (with the Indian group least affected). Thus far the basis on which South African higher education admissions decisions have been made has largely been performance on the NSC assessments. The consequences of this have been in part the racialized patterns of participation where 60% of the 20-24 White age group participate while only 12% of both Coloured and African 20-24 age groups participate [29]. The graduation and dropout rates equally reflect the racialized patterns with White students being 1.8 times more likely to complete a Mathematical Sciences degree within five years than their African counterparts and White students being 2.5 times more likely to graduate with a Business or Management degree within five years than their African counterparts [29].

If South African higher education is serious about changing these patterns it will have to ensure that curricula are better aligned to student needs. This is not to say that standards should be lowered, but rather that standards should be maintained by introducing mechanisms that enable students to navigate their studies in a manner that best suits their levels of preparedness. Higher education institutions have autonomy over their admission criteria, and admissions decisions are often sites of contestation. Admission criteria, as well as the assumptions underlying these criteria and the consequences for both admission and teaching and learning, need to be questioned. However, it is not the purpose of this paper to do so.

2.2. Extended programmes

Some myths that need to be dispelled are

- that students take three years for three year degree programmes and four years for four year degree programmes (only 27% of first time entrants do so);
- that extended degree programmes are for the minority and are inferior to the regular programmes.

The higher education sector has much to do to address the stigma associated with extended degree programmes, since there are often notions of deficit attached to those students who would benefit from these programmes. There is a need for both students and institutions reluctant to embrace extended degree programmes to have a sober look at the realities and to consider the admission and curriculum options that would best serve the students, the individual higher education institutions and the sector as a whole.

3. The criterion-referenced admission assessments and the norm-referenced school-leaving assessments

The two sets of assessments in the South African national landscape are fundamentally different in terms of purpose, intention, design and manner of delivery. The National Benchmark Tests are criterion-referenced, which means that they are "constructed to provide information about the level of a test-taker's performance in relation to clearly defined domains of content and/or behaviours (e.g. reading, writing, mathematics) that require mastery" [17] while the National Senior Certificate examinations are norm-referenced, which means that performance in a particular year is adapted to a 'norm group'. Norm-referenced tests are designed to sort and rank students, usually 'on a curve', not to see if they meet a standard or criterion. The National Senior Certificate attempts to find out whether learners are ready to exit the school system, while the National Benchmark Tests attempt to determine how ready prospective higher education students are for the demands of higher education. The paper first describes the National Senior Certificate, which is a set of norm-referenced assessments which aim to deliver statutory information for higher education admission. It then describes the criterion-referenced National Benchmark Tests, with its benchmarked categories of performance relating to formal study at institutions of higher learning.

3.1. The norm-referenced National Senior Certificate

The NSC assessments are norm referenced and therefore cannot easily be used to assess whether candidates meet a certain standard in a subject. For any NSC subject, part of the final score is made up of the course mark and then the scores are 'standardised' or 'normed' to the 5-year rolling average score for each subject. So while candidates may perform well compared to the norm, they may still fail to meet a certain standard in the subject being tested.

The Department of Basic Education determined the achievement scale for NSC subjects given in Table 1 below. The descriptions against the rating codes are not benchmarks or standards, but rather descriptive labels of percentage score ranges.

Table 1. National Senior Certificate (NSC) scale of achievement Grades 10-12.

Rating Code	Description	Score (%)
7	Outstanding achievement	80-100
6	Meritorious achievement	70-79
5	Substantial achievement	60-69
4	Adequate achievement	50-59
3	Moderate achievement	40-49
2	Elementary achievement	30-39
1	Not achieved	0-29

On completing the NSC, a candidate can qualify for higher certificate, diploma or degree study. Table 2 describes the criteria for entry into South African higher certificate, diploma or degree study.

Table 2. Criteria for Higher Certificate, Diploma and Degree study.

Qualification	Minimum Entry requirement
Higher Certificate	Pass NSC with at least an achievement rating of 2 (30-39%) for the Language of Learning and Teaching of higher education institution.
Diploma Pass	NSC with an achievement rating of 3 (40-49%) or better in four subjects. At least a rating of 2 (30-39%) for the Language of Learning and Teaching of the higher education institution.
Bachelor Degree Pass	NSC with an achievement rating of 4 (50-59%) or better in four subjects from the designated list. At least a rating of 2 (30-39%) for the Language of Learning and Teaching of the higher education institution.

3.2. The criterion-referenced National Benchmark Tests

The NBTs are based on test specifications [21] and use modern test theories [35] to determine test scores. Criterion-referenced benchmarks are set through standard setting methods, and these are used to place candidates in proficiency bands which describe both their preparedness for the demands of higher education and the extent to which the curricula should be responsive to the preparedness of the candidates they do admit. The NBTs assess students and prospective students in the three domains of Academic Literacy, Quantitative Literacy and Mathematics in the languages of higher education instruction, namely English and Afrikaans. The Academic Literacy test assesses a student's capacity to engage successfully with the language demands of academic study. The test is an assessment of the generic academic reading and reasoning ability of prospective applicants. The construct of academic literacy [8] on which the test is based has a well-theorised history ([1]; [13]; [34]; [7]) and empirical studies have been reported exploring associations between performance on this construct and academic performance in a wide range of South African higher education contexts ([9]; [10]). The Quantitative Literacy test assesses a student's ability to manage situations or solve problems of a quantitative (mathematical and statistical) nature in real contexts relevant to quantitative disciplines in higher education ([26]; [27]; [28]). The definition of quantitative literacy and the construct which underpins the NBT Quantitative Literacy test ([18]; [19]) is strongly influenced by the definition of numerate behaviour underlying the assessment of numeracy in the Adult Literacy and Lifeskills (ALL) Survey [20] and the New Literacies Studies' view of literacy as social practice ([33]; [32]; [24]). While the Academic Literacy and Quantitative Literacy assessments are generic in nature, the Mathematics test assesses a students' manifest ability related to mathematical concepts formally part of the school Mathematics curriculum relevant to the subject Mathematics itself and to mathematical disciplines such as Physics and Chemistry. The Mathematics assessment therefore assesses the degree to which learners have achieved the ability to manipulate, synthesise a number of different mathematical concepts, and draw strictly logical conclusions in abstract symbolic contexts [3]. These

higher-order skills underlie success in higher education mathematics. The Academic Literacy, Quantitative Literacy and Mathematics assessments make use of multiple choice items that are mapped onto the respective test specification tables. Responses are scored using the unidimensional three-parameter (a, b, c) Item Response Theory (IRT) model, where a = discrimination, b = difficulty, and c = guessing/pseudo-chance [35].

Academic Literacy, Quantitative Literacy and Mathematics items are scored dichotomously, that is, either as right or wrong. Each of the three assessments contains items that are common to all test forms in that domain. Modern test theories are used to ensure that the scores on different versions of the assessments are linked and equated [23] to ensure that performance on different versions of the test is comparable and is not a function of the version of the test that the candidate has written. The standard-setting method that is employed to determine the benchmarks is the modified Angoff method [22]. Table 3 provides a description of the Academic Literacy, Quantitative Literacy and Mathematics benchmark levels defining proficiency levels for degree study, the score ranges and appropriate institutional responses to candidates performing at these levels.

Table 3. National Benchmark Test performance standards and their interpretations for Bachelors study (BE)

Performance band	Score Range	Description
Proficient	BE AL: 64%-100% QL: 70%-100% MAT: 68%-100%	Test performance suggests that future academic performance will not be adversely affected (students may pass or fail at university, but this is highly unlikely to be attributable to their strengths or weaknesses in the domains tested). If admitted, students may be placed into regular programmes of study.
Intermediate	BE AL: 38%-63% QL: 38%-69% MAT: 35%-67%	The challenges identified are such that it is predicted that academic progress will be adversely affected. If admitted, students' educational needs should be met as deemed appropriate by the institution (e.g. extended or augmented programmes, special skills provision).
Basic	BE AL: 0%-37% QL: 0%-37% MAT: 0%-34%	Test performance reveals serious learning challenges: it is predicted that students will not cope with degree-level study without extensive and long-term support, perhaps best provided through bridging programmes (i.e. non-credit preparatory courses, special skills provision) or FET provision. Institutions admitting students performing at this level would need to provide such support themselves.

Since the scores of the majority of the South African higher education cohort have placed prospective students in the Intermediate band, it has been found productive to divide the Intermediate performance band into two, the Intermediate Upper and Lower bands as shown in Table 4. It is important to note that this division was not done through the standard-setting exercise but rather through taking the interval mean values.

This brief overview of the differences between the two assessment systems illustrate the potentially complementary nature of a norm-referenced assessment such as the NSC and a criterion-referenced assessment such as the NBTs. Data from 72 517 candidates who wrote both the NSC and NBTs are now used to explore whether there is empirical support for complementarity of the mathematics assessments in these two systems.

Table 4. National Benchmark Test Intermediate performance standards split into Upper and Lower and their interpretations for Bachelors study (BE)

Intermediate performance band	Score Range	Description
Intermediate Upper	BE AL:51%-63% QL:54%-69% MAT:52%-67%	Students are likely to need complementary support (additional tutorials, workshops, augmented courses, language intensive work)
Intermediate Lower	BE AL:38%-50% QL:38%-53% MAT:35%-51%	Students need to be placed in an extended degree programme

4. Diagnostic information arising from the NBT MAT test

The analysis of the NBTP MAT test results has a major role to play in informing institutional response to students' mathematical needs. These results have both a broad and more focused aspect. Broadly, the results provide benchmark levels (Proficient, Intermediate and Basic) which are indicative of the extent of the support institutions should be willing to provide (such as augmented programmes, or extended degree programmes for those students whose scores place them in the Intermediate or Basic categories), as discussed above. However, the results can be used in a more focused way by means of the sub-domain analysis (analysis of the test results in terms of specific content areas that may need attention).

For the MAT test the test specification matrix mapped onto tests over time provided a framework of items which 'hang together' in a particular way, thereby creating sub-domains M1 to M5, with each sub-domain represented in each test, as shown in Table 6 below. The sub-domain M2 *Numbersense* overlaps to some extent with the NBTP Quantitative Literacy test, and hence the lower proportion in the NBTP MAT tests.

Table 5. National Benchmark Mathematics (MAT) sub-domains

Sub-domain	Proportion of Test
M1 = Algebraic processing	25% – 30%
M2 = Number sense	5% – 10%
M3 = Functions and graphs	20% – 25%
M4 = Trigonometric functions and graphs	18% – 23%
M5 = Geometric reasoning	20% – 25%

Analysis of student performance in terms of these sub-domains can inform the type of support institutions need to provide, for example additional content where specific aspects of the curriculum have not been taught at school, or where significant lack of comprehension is evident.

We consider the sub-domain analysis for one specific faculty, viz. Business/ Commerce/ Management, shown in Figure 1.

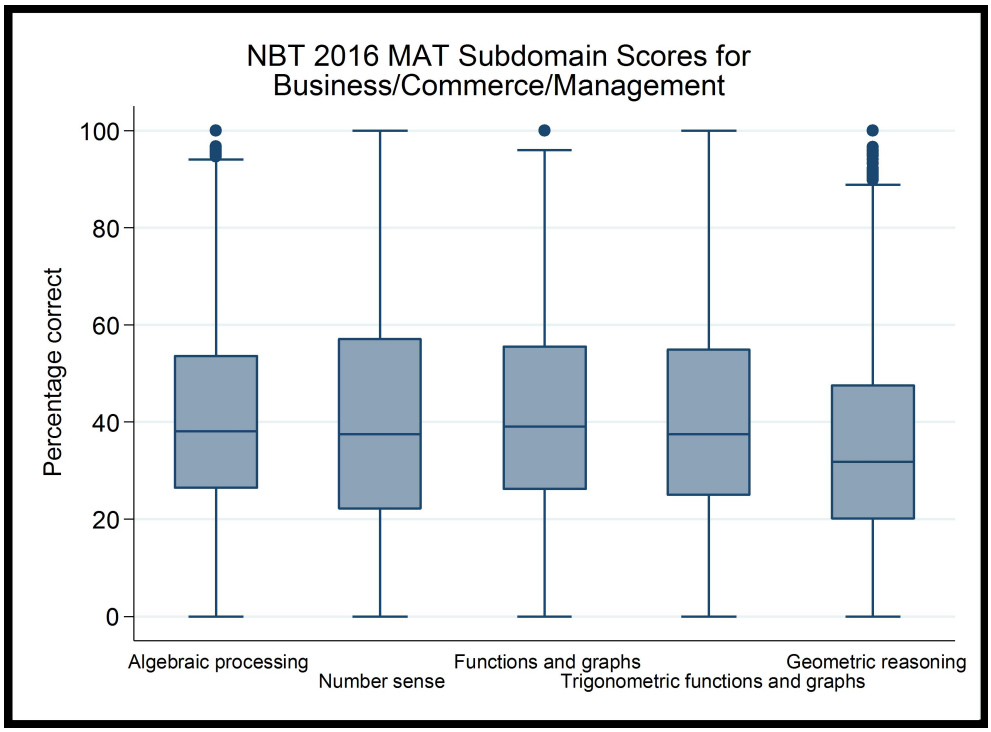

Figure 1. MAT Sub-domain scores for Business/Commerce/Management.

Lecturers dealing with these students may not be particularly concerned that the median for the sub-domain 'Geometric reasoning' is at the Basic benchmark, and that 75% of the candidates score less than 50% in this area. However, 'Functions and graphs', and 'Algebraic reasoning' are important components of programmes in Commerce and Economics. In both of these sub-domains the medians are in the Intermediate Lower band; only 25% of the candidates achieved scores of roughly 55% or more. Would first year lecturers expect this situation? Would they know how to respond? This example illustrates the type of information that sub-domain analysis can provide, in terms of assisting curriculum planners in determining the specifically targeted academic support that faculties and departments may need to provide; or in terms of identifying areas of weakness for individual students who can then access additional resources.

5. The case of prospective 2016 South African higher education candidates

After providing the background characteristics of the entire sample who wrote the NBT Mathematics test, we present the overall distribution of scores for those who wrote both the NSC and NBT Mathematics assessments. Although this sample does not include prospective students from all higher education institutions, it is reasonably representative of the South African entry-level cohort. To investigate the relationships between the two assessments, correlation analyses are first used to look at the concordant and divergent relationships. Bland Altman plots are then used to further explore the relationships between the three NBTs and their four cognate NSC counterparts. Lastly categorical methods are used to explore the relationships between the NBT benchmarks and the NSC percentage score ranges.

Some self-reported demographic characteristics of this sample are shown in Table 6. There were more female students (56.16%) than males in this sample. The majority of candidates were African (61.80%) and of all the home languages listed, the greatest proportion (29.30%) selected English as their home language.

Table 6. Demographic characteristics of the 51 276 prospective 2016 Higher Education candidates.

	number	%
Gender:		
Male	22 469	43.82%
Female	28 795	56.16%
Not specified	12	0.02%
Population group:		
African	31 689	61.80%
Coloured	5 027	9.80%
Indian	3 824	7.46%
White	10 567	20.61%
Not specified	169	3.30%
Home language:		
Afrikaans	5 989	11.68%
English	15 024	29.30%
isiNdebele	494	0.96%
isiXhosa	6 234	12.16%
isiZulu	6 219	12.13%
Sesotho	3 719	7.25%
Sesotho sa Leboa	4 166	8.12%
Setswana	2 853	5.56%
siSwati	1 224	2.39%
Tshivenda	2 337	4.56%
Xitsonga	2 254	4.40%
Other	763	1.49%
TOTAL	51 276	100.00%

Table 7 shows how the students performed on the NSC Mathematics assessment and Table 8 shows how the scores of the sample of students were distributed over the NSC rating codes.

Table 7. Descriptive statistics for the prospective Higher Education Entrants on the NSC Mathematics assessment (MTHN).

n	Mean	SD	Minimum	1st Quartile	Median	3rd Quartile	Maximum
56 662	57.8	18.6	3	44	58	72	100

Table 8. Frequencies of performance for the prospective Higher Education Entrants on the NSC Mathematics assessment (MTHN).

1	2	3	4	5	6	7
3572 (6.3%)	6774 (12.0%)	9200 (16.2%)	10572 (18.7%)	9961 (17.6%)	8622 (15.2%)	7961 (14.0%)

It is clear that nearly two-thirds (65.5%) were classified as having achieved the NSC at or above level 4 in Mathematics. These results suggest that the majority of these students would have been eligible to enter higher education, the assumption being that they should be able to cope with the Mathematics demands of higher education.

Table 9 shows the performance of the prospective students on the NBTs Mathematics assessment (MAT).

Table 9. Descriptive statistics for the prospective 2016 Higher Education Entrants on the NBT MAT assessment.

n	Mean	SD	Minimum	1st Quartile	Median	3rd Quartile	Maximum
53039	40.60	16.4	2	28	35	50	97

Table 10 shows the score distribution of the sample of students over the NBT Bachelor proficiency bands for those who achieved a Bachelors NSC pass. It is clear that the only about ten percent (10.49%) were considered Proficient in Mathematics. Most of the students had scores in the Intermediate band: 47.78%. These results suggest that the majority of these students would have needed some kind of extended support in Mathematics.

Table 10. Frequencies of performance for the prospective 2016 Higher Education students who were eligible for Bachelor studies using the NBT Bachelor benchmarks.

MAT Benchmark band	n	%
Basic	18801	41.74
Intermediate Lower	13643	30.29
Intermediate Upper	7879	17.49
Proficient	4724	10.49
Total	45047	100.00

If we interrogate this data a little further, according to the faculties to which these candidates applied, we find, for example, that in a heavily mathematically dependent faculty such as Engineering and the Built Environment, while 33% of the candidates fell in the Proficient and Intermediate Upper bands, the median fell into the Intermediate Lower band. For the Science/Mathematics faculty, 17% of the candidates were in the Proficient or Intermediate Upper bands, and the median was close to the Basic benchmark (34%). The NBT MAT results for those applying to Education are a cause for concern. The NBT MAT test was presumably written by those wanting to become mathematics teachers, since Education in general does not require mathematics as a programme component. Only 4% of the scores of these candidates fell into the Proficient or Intermediate Upper bands, and the median of their scores was in the Basic band. The curriculum for prospective mathematics and science teachers should take this into account.

We now look at the relationships between the two sets of assessments.

6. Relationships between the two sets of assessments

We look at a) the relationship between the two sets of assessments using correlation analyses in order to investigate the convergent and discriminant (also called divergent) validity; b) the scatter plots and Bland Altman plots to investigate the relationships between scores on the NSC assessments that are cognate to the NBT assessments; and c) the relationship between the NSC assessment performance levels and the NBT proficiency categories.

6.1. Correlation analyses: the convergent and discriminant relationships

Convergent validity is the degree to which a test is similar to (converges on) other cognate tests to which it should theoretically be similar. Discriminant validity on the other hand is the degree to which a test is not similar to (diverges from) other tests to which it should theoretically not be similar. The Pearson linear correlation coefficient is used to measure the extent of convergent and discriminant validity.

The Pearson correlation coefficient, $r = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2}\sqrt{\Sigma(Y-\bar{Y})^2}}$, is a scale-free measure that assesses the degree to which two variables X and Y are linearly related. It takes on a value between $+1$

and -1 inclusive, where 1 is total positive correlation, 0 is no correlation, and -1 is total negative correlation. The correlation coefficient can be interpreted as the effect of a change in one variable related to a change in a second variable. The square of r is called the coefficient of determination which indicates the proportion of the variance in the second variable that is explained by the first variable. Cohen (1988) attempted to address the issue of interpreting effect size estimates relative to other effect sizes. He suggested the following guidelines for interpreting correlation coefficients in the social sciences: small $(r = 0.1)$, medium $(r = 0.3)$, and large $(r = 0.5)$. However, Cohen chose these quantities to reflect the typical effect sizes encountered in the behavioral sciences as a whole – he warned against using his labels to interpret relationship magnitudes within particular social science disciplines or topic areas. His general labels, however, illustrate how to go about interpreting relative effects. Carlson and Herdman (2012) recommend using r above 0.7 as evidence for convergent validity whereas those below 0.5 should not be seen as evidence.

The correlations between the NBT and NSC assessments are presented for the entire sample $(n = 72517)$ of first year prospective students in South African higher education in Table 11. Performance on the NBT Mathematics assessment is most convergent with Mathematics $r(51678) = .78, p < .01$; Physical Sciences $r(42225) = .73, p < .01$; Information Technology $r(2360) = .69, p < .01$; Accounting $r(16611) = .63, p < .01$; Life Sciences $r(38901) = .62, p < .01$; and Engineering Graphics and Design $r(4311) = .60, p < .01$. These are all fairly consistent with expectations.

Table 11. Correlations between NBT Mathematics and NSC assessments for prospective first year students.

Code and Description	r	p	N
ACTN : Accounting	0.63	0	16611
AFFN : Afrikaans First Additional	0.41	0	22577
AFHN : Afrikaans Home Language	0.52	0	5912
AGSN : Agricultural Sciences	0.49	0	3489
BSTN : Business Studies	0.42	0	10546
CNSN : Consumer Studies	0.55	0	1735
DRAN : Dramatic Arts	0.46	0	1072
ECON : Economics	0.55	0	5616
EGDN : Engineering Graphics and Design	0.6	0	4311
ENFN : English First Additional	0.46	0	25448
ENHN : English Home Language	0.56	0	27591
GEON : Geography	0.55	0	19330
HISN : History	0.43	0	4892
INFN : Information Technology	0.69	0	2360
LFON : Life Orientation	0.37	0	53039
LFSN : Life Sciences	0.62	0	38901
MTHN : Mathematics	0.78	0	51678
MTLN : Mathematical Literacy	0.41	0	1763
MUSN : Music	0.59	0	536
PSCN : Physical Sciences	0.73	0	42225
RELN : Religion Studies	0.4	0	344
VSAN : Visual Arts	0.46	0	1423

6.2. Scatter plots and Bland Altman plots

Researchers often need to compare two methods of measurement, or a new method with an established one, to determine whether these two methods can be used interchangeably or whether the new method can replace the established one. In most of these situations, the 'true' value of the measured quantity is unknown.

In 1986, Bland and Altman advocated the use of a graphical method to plot the difference scores of two measurements against the mean for each measurement and argued that if the new method

agrees sufficiently well with the old, the old may be replaced. Here the idea of agreement plays a crucial role in method comparison studies.

The Bland–Altman method calculates the mean difference between two measurements (the 'bias'), and 95% limits of agreement as the mean difference (1.96 sd). It is expected that the 95% limits include 95% of differences between the two measurement methods. The plot is commonly called a Bland–Altman plot and the associated method is usually called the Bland–Altman method.

In this part of the paper the Bland-Altman method and plots are used to investigate the relationship between performances on the NBT Mathematics and the cognate NSC Mathematics counterpart.

From the correlations in Table 11, the scatter plot given in Figure 2 and the Bland-Altman plot (Figure 3) for NBT Mathematics (MAT) and NSC Mathematics (MTHN) it can be seen that even though MAT is correlated with MTHN $r(51678) = .78, p < .01$ the MAT scores are on average 18.1 percentage points lower than the MTHN scores. Also for the mean MAT and MTHN scores below 40% the difference is closer to zero whereas between 40% and 75% many of the differences are outside the lower 95% confidence interval.

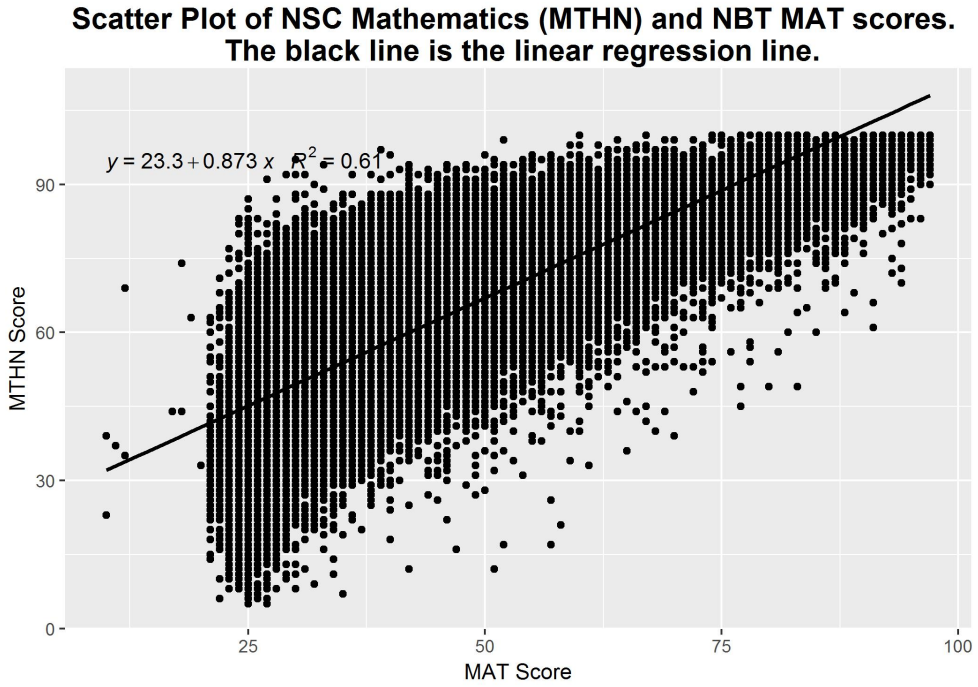

Figure 2. NSC Mathematics (MTHN) and NBT MAT scores for 2015. The black line indicates the linear regression line.

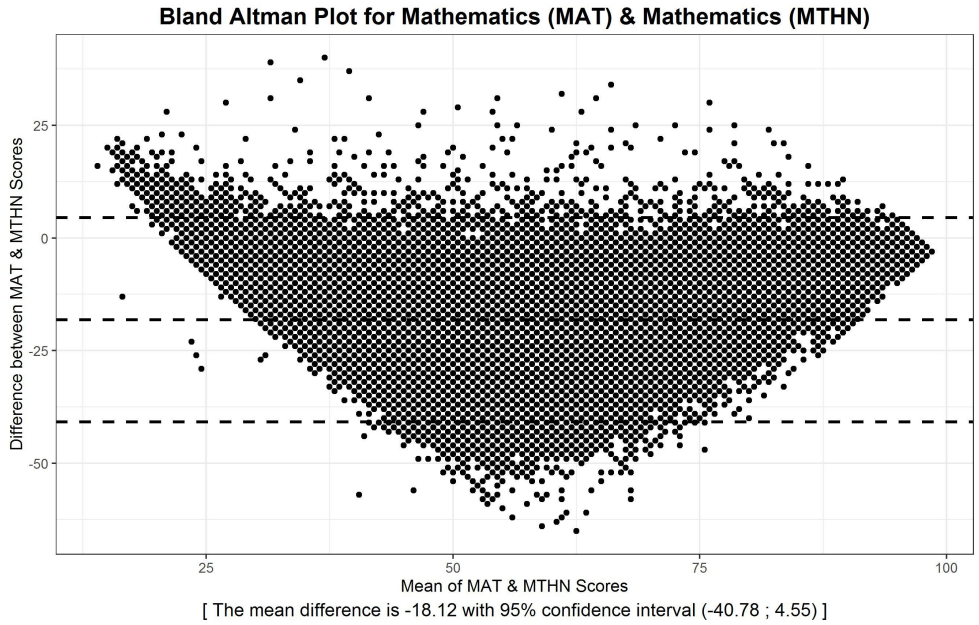

Figure 3. Bland-Altman plot of the difference between NBT Mathematics (MAT) and Mathematics (MTHN) against the mean of MAT and MTHN.

The paper now presents the relationship between performances on the NBT Mathematics (MAT) and the NSC Mathematics (MTHN) assessments using NBT MAT benchmark categories and NSC achievement levels for those candidates who achieved the NSC with a Bachelor pass.

A chi-square test of independence was performed to examine the relation between NBT Mathematics and NSC Mathematics. The relation between these variables was significant, $X^2(18, N = 44067) = 35291, p < .01$ for the prospective higher education students who achieved the NSC with a Bachelor pass. Those students with low achievement levels on the MTHN were less likely to achieve MAT proficient scores than were those who achieved high levels of performance on the MTHN and these patterns were consistent across the different MTHN levels. The following chart in Figure 4 clearly show these associations visually as well.

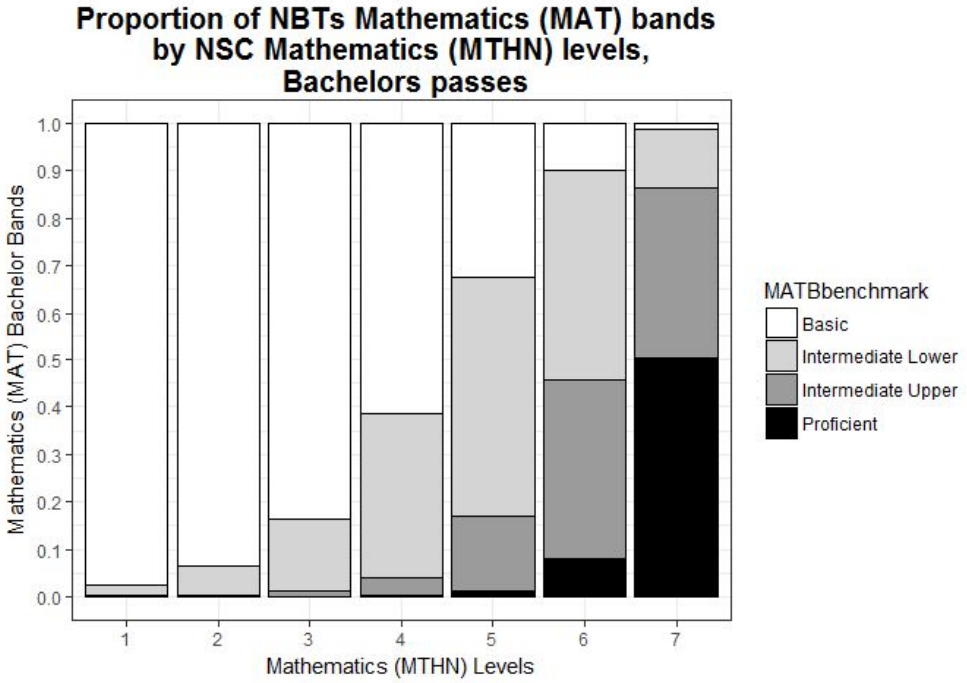

Figure 4. Percentage distribution of NBT MAT scores by Bachelor proficiency bands for different NSC Mathematics levels achieved for NSC candidates who achieved a Bachelor pass.

7. The case of three faculties at a South African higher education institution

The NBTs are by design an attempt to address the throughput challenges faced by higher education in South Africa. When institutions admit students with the full knowledge of their less than adequate levels of academic preparedness it is imperative that appropriate teaching and learning environments be created. However, too often higher education institutions are not sufficiently responsive to the needs of the students and in the process students have a particularly bad teaching and learning experience and may drop out. To investigate how the two assessments together could predict first time entrants' performance at the end of six years, we track the 2 566 first time entering students who entered three faculties (Commerce, Engineering and the Built Environment, and Science) at a South African University in 2009 and classify their last academic standing code into one of three categories, 'Fail', 'Continuing' and 'Graduate'. The academic standing code is a code of achievement (or performance) at the end of each year at this particular higher education institution. Of the 2 566 first time entrants, 2 375 wrote the NBT Academic Literacy and Quantitative Literacy assessment and 2 253 wrote the NBT Mathematics assessment at the beginning of their studies in 2009. Of these 2 566 first time entering students, 2 035 wrote the NSC English (either Home Language or First Additional Language) and 2 027 wrote the NSC Mathematics assessments.

We provide the background characteristics of the entire sample, and the overall distribution of scores for those who wrote the two NSC and three NBT assessments. In addition, we present the academic standing of the sample of students after six years and the associations between performance on the NSC and NBT Mathematics assessments, and the academic standing for the cohort of students who wrote these assessments.

Some self-reported demographic characteristics of this sample are shown in Table 12. The majority of candidates were African (39.95%) and the majority reported English (62.04%) as their home language. There were more male students (56.27%) than females in this sample.

Table 12. Demographic characteristics of the 2 566 First Time Entrants.

	number	%
Gender:		
Male	1 444	56.27%
Female	1 119	43.61%
Not specified	3	0.12%
Population group:		
African	1 025	39.95%
Coloured	305	11.89%
Indian	322	12.55%
White	890	34.68%
Not specified	24	0.94%
Home language:		
Afrikaans	60	2.34%
English	1 592	62.04%
isiNdebele	9	0.35%
isiXhosa	250	9.74%
isiZulu	218	8.50%
Sesotho	73	2.84%
Sesotho sa Leboa	464	7.3%
Setswana	79	3.08%
siSwati	32	1.25%
Tshivenda	55	2.14%
Xitsonga	27	1.05%
Other	97	3.78%

Table 13 shows the performance of students on the two NSC Mathematics assessment and Table 14 shows the distribution of scores of the sample of students over the NSC rating codes.

Table 13. Descriptive statistics for the First Time Entrants on the NSC Mathematics (MTHN) assessment.

n	Mean	SD	Minimum	1st Quartile	Median	3rd Quartile	Maximum
2027	83.94	9.59	45	78	85	91	100

Table 14. Frequencies of performance for the First Time Entrants on the NSC Mathematics (MTHN) assessment.

Rating code	n	%
4: Adequate achievement	27	1.33
5: Substantial achievement	120	5.92
6: Meritorious achievement	442	21.82
7: Outstanding achievement	1437	70.93
Total	2253	100.00

It is clear that nearly all (92.74%) were classified as having achieved the NSC at either Meritorious or Outstanding levels in Mathematics. These results suggest that the majority of these students would have been able to cope with the Mathematics demands of higher education. Table 15 shows the performance of students on the NBT assessments.

Table 15. Descriptive statistics for the First Time Entrants on the NBT Mathematics (MAT) assessment.

n	Mean	SD	Minimum	1st Quartile	Median	3rd Quartile	Maximum
2253	48.78	11.85	0	40	48	55	80

Table 16 shows the distribution of the scores of the sample of students over the proficiency bands. Of this sample, 14.91% were considered Proficient in Mathematics. Most of the students (76.25%) had scores in the Intermediate band. These results suggest that the majority of these students would have needed some kind of extended support in Mathematics.

Table 16. Frequencies of performance for the First Time Entrants on the NBT Mathematics (MAT) assessment.

Benchmark band	n	%
Basic	199	8.83
Intermediate Lower	847	37.59
Intermediate Upper	871	38.66
Proficient	336	14.91
Total	2253	100.00

The Academic Standing results are presented for the entire sample (n = 2 566) of first time entrants into the Commerce, Engineering and the Built Environment, and Science faculties at a South Africa university. Table 17 indicates that two thirds of the students graduated and just under a quarter failed while 9% were still studying.

Table 17. Frequencies of academic standing at the end of six years for the First Time Entrants.

Academic Standing	n	%
Graduation (GRAD)	1719	66.99%
Continue (CONT)	231	9.00%
Dropped out (FAIL)	616	24.01%
Grand Total	2566	100.00%

When we look at the association between student performances on the NSC Mathematics (MTHN) and NBT Mathematics (MAT) assessments at the beginning of their studies with their subsequent academic standing after six years we find that it is high for both assessments.

From the Pearson Chi-square test statistics in Table 18, there is a statistically significant (simulated $P<0.001$) association between performance in both the assessments and academic standing at the end of six years. The large Chi-square values and narrow confidence intervals for the simulated p-values suggest that these associations are strong.

Table 18. Pearson's Chi-squared test for measuring the association between the NSC and NBT assessments and Academic Standing categories at the end of six years.

Pearson's Chi-squared test	NSC MTHN	NBT MAT
Chi-square	127.6819	156.7539
two-sided P-value	8.55E-24	2.88E-31
simulated P-value	0	0
99%CI of simulated P-value	0 to 0.000460411	0 to 0.000460411
Number of simulations	10000	10000

The following two charts in Figures 5 and 6 clearly show these associations visually. The statistics generated with the Microsoft Excel add-in for the statistical analysis of contingency tables [30] in Table 18 support the conclusion that the associations are significant.

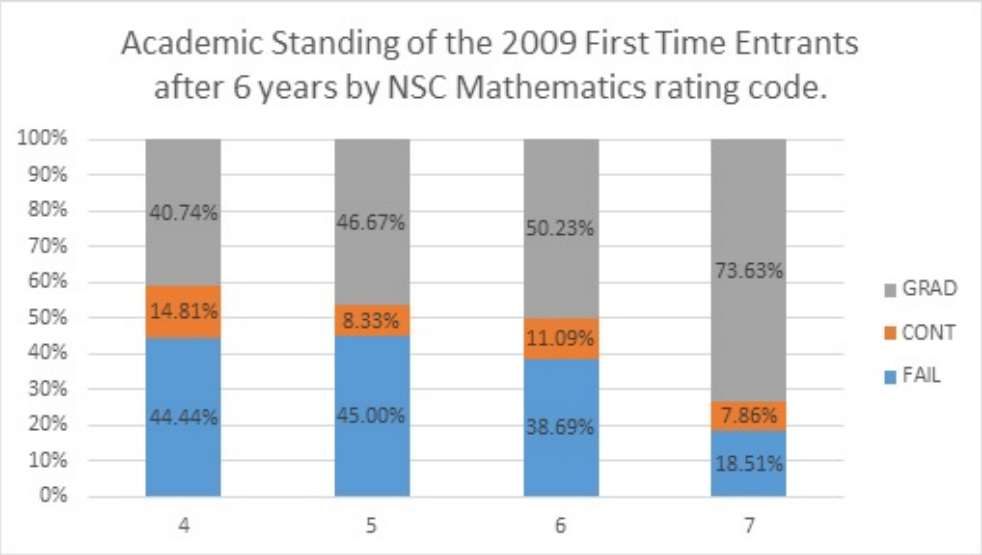

Figure 5. Percentage of 2009 First Time Entrants in the three academic standing categories by NSC Mathematics rating codes.

In Figure 5, graduation and failure patterns at the end of six years were similar for the students with NSC Mathematics levels 4 to 6 rating codes, and those with NSC Mathematics level 7 results performed substantially better both in terms of graduation and failure. From Table 18, the probability associated with the Chi-square statistic of 127.6818 is less than 0.001 and the confidence interval for the simulated p-value is very narrow, suggesting that there is a significant relationship between the NSC Mathematics assessment levels and Academic Standing variables.

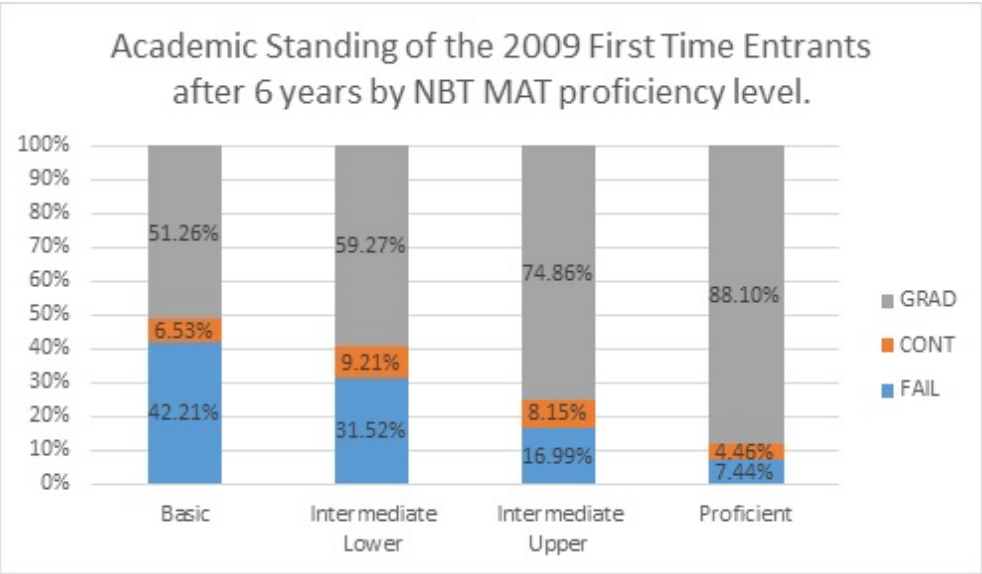

Figure 6. Percentage of 2009 First Time Entrants in the three outcome categories by Mathematics proficiency bands.

In Figure 6, graduation patterns at the end of six years increased from low to high NBT Mathematics performance levels and failure on the other hand decreased from low to high levels. From Table 18, the probability associated with the Chi-square statistic of 156.7539 is less than 0.001 and the confidence interval for the simulated p-value is very narrow, suggesting that there is a significant relationship between the NBT Mathematics assessment scores and Academic Standing variables.

This institutional case study clearly indicates that for this institution performance on the NSC and NBT Mathematics assessments are associated with subsequent academic standing and that it would have been appropriate for this institution to consider the use of the NBT scores to place students in extended degree programmes and to ensure that these students were provided with appropriate teaching and learning environments.

8. Implications for Higher Education

The notion of under-preparedness can be applied to both students and higher education institutions. Boughey [4] stresses that the notion of under-preparedness implies 'deficiency' in the students only and does not recognise that higher education institutions themselves are underprepared to meet the needs of the students that they admit. University admissions and teaching need to take into account the capabilities of the students that they accept, place them appropriately and make changes to the curriculum to address the 'articulation gap' [29] between the demands of curricula and the level of many students' academic literacies. In order to design a more responsive curriculum, lecturers and curriculum developers in higher education need the kind of information provided by the two tests about the capabilities of students.

In order to broaden access to the South African higher education sector, so that students who have not yet had a chance to demonstrate their potential can be included, it is necessary to admit students from educationally disadvantaged backgrounds. Some of the criteria associated with educational disadvantage are home and school backgrounds, whether these students are first generation higher education students and whether they have gone to private schools or the equivalent. If students are to be admitted into higher education they need to be placed in the most appropriate form of curriculum provision. It is for this purpose that the extended curriculum programmes exist and the NBTs are well suited to identify those students who have the potential to succeed if they are provided with the appropriate supportive teaching and learning environments. The NBTs can also apply to students in the Basic band, and potentially identify which of these students have the potential to succeed with extensive support. This support may possibly be beyond what a university could realistically provide, but with appropriate support and guidance such students could find alternative study routes. The NBTs can thus also be seen to have the potential to filter students who can be directed to other forms of higher education.

There are variations of these extended degree programmes within and between institutions. Some programmes do the first year over two years while others use the first year as a foundation year. Essentially these extended degree models all subscribe to the idea of 'more time on task' to achieve their goals of providing a more appropriate teaching and learning environment. The problem however is that while students may be able to cope with the reduced curriculum in the first year, the second year then becomes the barrier. In "A proposal for undergraduate reform in South Africa: The case for a flexible curriculum structure" (Council on Higher Education 2013) a more bold approach is proposed. The approach that is proposed here is to go beyond seeing the first year as needing special attention and to focus instead on the entire curriculum programme. This is done for example by spreading the three-year curriculum over four years and the four-year curriculum programme over five years. In both conceptualizations of the extended foundation programme, whether it is the first year or the entire programme that is extended, the placement issue is of key importance.

As noted earlier in the paper, the South African graduation and dropout rates are of concern but even more so are the racialized patterns of these rates [29]. The current admission requirements and curricula appear to reproduce the historical apartheid patterns. Higher education policies and

practices need to mitigate racialized schooling and the manner in which racial classifications continue to play out in terms of higher education participation, graduation and drop-out rates.

This paper has argued that extended curriculum provision in the higher education landscape is necessary and should continue into the foreseeable future. It is necessary to use some means to determine which of the extended curriculum or regular programmes are best suited to individual students. While norm-referenced assessments may be a statutory requirement for higher education study, criterion-referenced assessments such as the National Benchmark Tests can provide the kind of information which is needed to make decisions about which curricular route best suits students in an attempt to improve the graduation rates and address the drop-out rates.

Author Contributions: "Robert Prince conceived and designed the paper; Robert Prince performed the analysis; Robert Prince analyzed the data; Carol Bohlmann co-wrote the paper."

Conflicts of Interest: "The authors declare no conflict of interest."

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