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EXPLORING THE SCHOOL-UNIVERSITY MATHEMATICS SKILLS GAP FOR ECONOMIC SCIENCES

ABSTRACT

The training of highly skilled persons for the areas of Economics and Commerce requires that degree students upon entry need certain knowledge and skills in mathematics including aspects of statistics. The context is distance education and entry students seem unable to cope with the requirements of the mathematics-based topics that they need to study at the first year of tertiary education. It resulted in university staff speculating about a gap in pre-knowledge and skills. This study aims to investigate this phenomenon, starting with content and Revised Bloom's Taxonomy analyses of final year school examination papers in mathematics, comparing it with similar analyses of first-year mathematics-based module examinations in the Economic sciences. Students that passed mathematics at school are supposed to have had adequate preparation for the first level Bachelor of Commerce. Coping with routine procedures mainly upon exit from secondary education does not signal well for the subsequent training of economists and commerce students. The situation seemingly does not improve at tertiary level where there is a further emphasis on routine procedures compared to higher order thinking skills.

Keywords: *Mathematics pre-knowledge; economic sciences; Revised Bloom's Taxonomy for Mathematics; financial mathematics; distance education.*

1. INTRODUCTION

Year after year South Africans in general, and university lecturers involved with the teaching and learning of numeracy skills in particular, anxiously await the results of the annual final school year (Grade 12 or matric) examination in mathematics. It is well known that the stakes are exceptionally high because these results are determining factors for the future and studies of many young people. Mathematics marks are not only used as entry requirements for the natural, engineering, medical and accounting sciences, but increasingly for economic and management sciences – the context of this paper. The impact of mathematics has been the topic of various academic studies shown by two of numerous examples (Lithner, 2011; Wood *et al.,* 2012), but it is also regularly publicised in the local news media, from headings such as “School maths failing varsity entrants” (Nkosi, 2013) and “Adding up SA’s dire maths emergency” (Tau, 2014) to “Shocking facts about school maths in South Africa” (News24 Wire, 2015). We will be comparing the mathematics skills as assessed in the final year of school with that in the first year of university study for the Bachelor of Commerce (BCom) degrees. The study was prompted by the stark reality that for years now, students have been admitted to BCom degrees at the University of South Africa (Unisa) with university exemption based on their school results, but within the first year, the dropout rate could on average be more than 50%. Of those students persisting and making it to the semester examinations, the average pass rate for first-year Economics for example could be below the 50% mark (Pretorius *et al.,* 2009). The effectiveness of the school and university systems to enhance the learning experience in mathematics-based courses for economy and commerce students, is questioned here.

2. PURPOSE OF THE STUDY

The aim of this study was firstly to investigate the mathematics skills and skills levels developed in the South African public secondary school system. It was done by analysing the final year examination papers of the past 5−6 years to determine the pre-knowledge and skills that students were supposed to have by the end of their school careers with a view to studying Economics and Commerce. These skills are mainly mathematical process skills as prescribed by the Department of Basic Education of South Africa (DBE, 2011). Secondly we analysed the first-level BCom university papers dealing with numeracy of the same period to establish any gaps in the pre-knowledge and skills students might have and to what extent the university modules rely and build on the school learning. Finally, we compare and propose improvements to the learning of mathematics for the economic and management sciences with a view of eventually advancing the learning and success rates of students.

3. LITERATURE REVIEW

3.1 Secondary-tertiary transition

For learners who choose the secondary to tertiary route, this transition is only one of a multitude of “transitions” relevant in the milieu of the teaching and learning of mathematics (Gueudet *et al.,* 2016). The transition mentioned often results in a so-called gap in mathematical knowledge and skills. In the literature, the context for researching this gap is mainly in pure mathematics, science and engineering; therefore, references from these areas and related journals are included. Lately studies in other areas appeared, for example indicating the mathematics pre-knowledge needed to study Accounting (Mkhize, 2019).

Various methods could be utilised to answer the question posed by a Norwegian study “Are students transitioning from the secondary level to university studies in mathematics and engineering adequately prepared for education at the tertiary level?” (Nortvedt & Siqveland, 2019). The gap could be determined by curriculum studies, comparisons or mathematics diagnostic tests with or without prior notice. The National Benchmark Test (NBT) is a local example of such a diagnostic test (NBT, 2020). It was anticipated that before we could venture into situations of diagnostic testing or anything else, we needed to start with the basics, “where it starts”, the curricula determining what should be learnt and then the final assessments determining what has been achieved.

3.2 International examples

Gaps in mathematical knowledge and skills are anticipated in developing countries with education challenges, but Nortvedt and Siqveland (2019) reported this gap even for Scandinavian countries such as Norway who perform above the international level on tests such as the Programme for International Student Assessment (PISA, 2020) and Trends in International Mathematics and Science Study (TIMSS, 2020). An initial approach is to think in terms of a comparison between secondary and tertiary content, but the challenges actually stem from primary and lower secondary level where difficulties handling symbolic language and concepts are introduced or experienced. Basic mathematical knowledge i.e. numbers, algebra, measurement and geometry seem to be key, because these are building blocks for students to develop, for example, an understanding of algebra and functions.

The mismatch between the nature of entrants' pre-tertiary mathematical experiences and subsequent tertiary level mathematics-intensive courses has been described in the United Kingdom as substantial and labelled the "Mathematics problem" (Hourigan & O'Donoghue, 2007). University mathematics lecturing staff agreed that grades achieved in central state examinations were not comparable to grades ten years earlier. The shift to mass education during these years resulted in the education system becoming exam-orientated and the Leaving Certificate Examination (LCM) in Ireland for example would therefore be the foremost reason for studying mathematics. Pacing through topics to cover the LCM and routine in classrooms following a day-to-day methodology, made the learning environment teacher-centred and the mathematics mastery of algorithmic procedures difficult. Dialogue in classrooms became only teacher-initiated with pupils believing that their role was passive, that of listener and copier. Schools were pressured to deliver good LCM results that in turn seriously weakened the greater aim of providing a high-quality mathematics education.

Three studies in Ireland elaborated on the 2007 work 7−9 years later (Faulkner *et al.,* 2014; Treacy & Faulkner, 2015; Treacy *et al.,* 2016). The first study confirmed that after several different routes were provided to widen access to higher education, the result that panned out over time, was "beginning undergraduates with lower prior academic attainment, including mathematics, than ever before" (Faulkner *et al*., 2014: 650). Wider access required support services and they utilised discrimination analysis and a diagnostic test to classify students. The performance of students in higher education mathematics was best predicted by prior mathematical attainment. Focusing on mathematics of service modules in science and technology, studying a cohort of students for the ten year period 2003−2013, the second study found an overall decline of 12.6% in basic mathematical skills of beginning students and an increase in at-risk students from 4% to 21%. This all happened during the time the number of students entering service modules almost doubled. Mathematics remained the strongest predictor of successful progression of students through tertiary studies. Ireland had a curriculum change during the period 2008−2014 that prompted the third study to probe more intensively for grade dilution. "Project Maths syllabus" placed renewed emphasis on problem-solving in practical contexts instead of focusing on procedural knowledge. The study just confirmed previous results; there were significant declines in beginning undergraduate students' performance of basic mathematical skills for topics such as arithmetic, algebra, geometry and calculus.

Some countries such as the USA use placement tests to consider school leavers for further study. In a fairly large study in the Midwest, researchers did not find any relation between students' high school mathematics curricula and their calculus readiness placement test recommendations, implying that students were not disadvantaged by a particular high school mathematics curriculum; especially considering traditionally commercially developed versus National Science Foundation funded curricula. The latter focusing on developing conceptual reasoning abilities and skills in modelling-based problems (Norman *et al.,* 2011).

One international study in the domain of commerce and finance worth mentioning deals with threshold concepts in finance such as leverage/gearing, liquidity, risk/return, arbitrage, etc. (Hoadley *et al.,* 2015). The work was conducted in five countries namely, Australia, Canada, New Zealand, South Africa and the United Kingdom. They identified threshold concepts that are considered central to mastery of finance and it was established that statistical concepts such as probability, randomness, regression, normal distribution, etc. underpin financial modelling. In the South African context, these statistical concepts point towards prior learning in Mathematics and the impact thereof.

3.3 Local examples

A local example of probing the secondary-tertiary transition over a ten-year-period is research carried out at the North-West University. A curriculum change also prompted the results reported in 2010 (Benadé & Froneman, 2010). The example is from engineering when the first cohort of students completed their schooling in the time of the National Curriculum Statement (NCS) policy. The transition from secondary to tertiary mathematics required a shift from elementary to advanced mathematical thinking, resulting in a disjunction between the two levels. Considering all first-year students for programmes including a mathematics module in either science, engineering, commerce or arts, the researchers compared a traditional transmission knowledge-based curriculum (TKC) group with an outcomes-based education (OBE) group (Froneman *et al.,* 2015). The OBE cohort showed poorer algebraic skills after a statistically significant difference was established for procedural knowledge. Froneman and Hitge (2019) recently included a cohort of students from the revised OBE curriculum as documented in the Curriculum Assessment Policy Statement (CAPS) with that of the transmission knowledge-based and outcomes-based education groups to obtain an overview of the effect of three national curricula. They found little difference in practice for the three representative cohorts entering natural science and engineering based on a diagnostic test. All three cohorts performed poorly on questions of the test requiring conceptual understanding, despite the intention of the two outcomes-based education curricula to develop higher-order cognitive skills.

3.4 Revised Bloom's Taxonomy

We used the Revised Bloom's Taxonomy (RBT) for Mathematics (Radmehr & Drake, 2019) as a framework in this study. Application of the framework is found in various contexts; for example, in the assessments of first-year accounting textbooks (Ngwenya & Arek-Bawa, 2020), analysing assessment systems (Uma *et al.,* 2017) and the final mathematics examination problems in junior high school (Himmah *et al.,* 2019). We did not find examples in the context of the transfer of mathematics skills from secondary school to economic sciences at university level and specifically for distance education.

4. BACKGROUND

The University of South Africa (Unisa) is the only public open distance e-learning (ODeL) university in the South African higher education sector and the largest in Africa (Unisa, 2021). Currently it serves more than 350 000 students per academic year, nearly one third of South African students (Unisa, 2020). The College of Economic and Management Sciences (CEMS) offers BCom degrees and hosts approximately 27% of the students. The Department of Decision Sciences, formerly Quantitative Management, is responsible for the numeracy, mathematical and statistical aspects of the teaching in the college.

The merger approach to the higher education system (SAG, 2002) during the first five years after the millennium, resulted in Unisa becoming a so-called comprehensive university offering the spectrum of post-school qualifications, including undergraduate and postgraduate degrees, diplomas and one-year certificates. CEMS had to adjust to a national expectation that all students, irrespective of mathematical background, should be catered for within this comprehensive system. Figure 1(a) gives an overview of the progression paths devised and used from 2013−2019. Grade 12 Mathematics was originally not an admission requirement to register for certain BCom degrees (Unisa, 2004). From 2013 the admission requirement was raised to a minimum of 60% in Grade 12 Mathematics. Mathematical Literacy was no longer considered as an admission requirement for these degrees. Two modules at the first level Quantitative Modelling DSC1520 and Introductory Financial Mathematics DSC1630 aim to strengthen students' mathematical and statistical competencies. Extended degrees in a Foundation Programme spanning four years were introduced for prospective students with Grade 12 Mathematics marks between 50% and 60%. Business Numerical Skills A and B (FBN1501 and FBN1502) were introduced in 2013 to support and develop the mathematical skills of these students.

Students with less than 50% for Grade 12 Mathematics, with Grade 12 Mathematical Literacy or older persons without mathematics were articulated to a Higher Certificate in Economic and Management Sciences. After completion of ten 12-credit NQF level 5 modules, students could enter the BCom degree. Two of the modules, Basic Numeracy (BNU1501) and Elementary Quantitative Methods (QMI1500), address numeracy skills and reside with the Department of Decision Sciences. A blended delivery model that includes online and paper-based resources is used to provide students with learning support.

The admission criterion of 60% minimum for Grade 12 Mathematics to enter BCom degrees resulted in low registration numbers for these degrees. This requirement was not in line with those for similar degrees at other South African institutions. Some departments in the College, where the discipline did not require a high level of mathematics skills such as Public Administration and Tourism, applied to lower the admission criteria for their degrees. It resulted in a decision by the College Tuition and Learning Committee to lower the minimum admission requirement for a BCom degree to 50% for Grade 12 Mathematics. A prospective student who does not meet this requirement, would be referred to the Higher Certificate in Economic and Management Sciences (Figure 1[b]). The criteria for the extended degrees were changed to a mark between 40% and 50% for Grade 12 Mathematics. But funding for the extended degrees terminated and from 2020 these degrees are not offered.

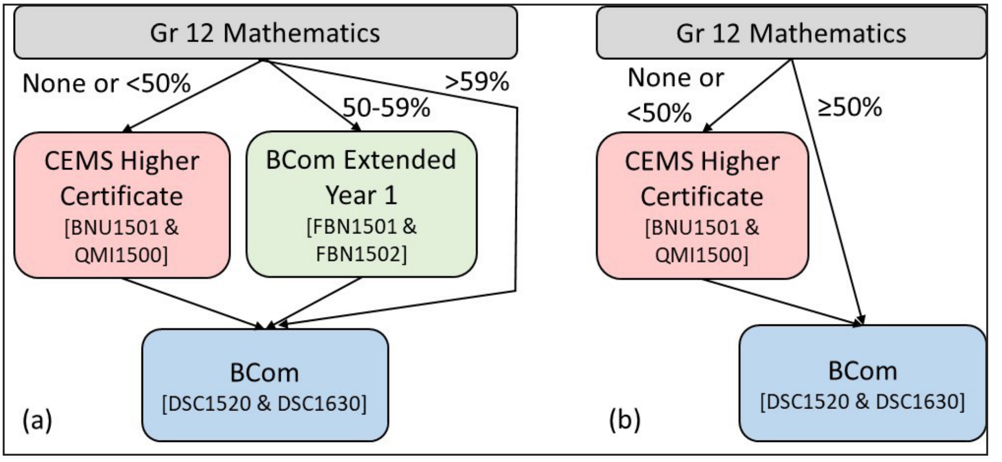


Figure 1: Progression paths for students of two periods (a) 2013−2019 and (b) since 2020.

5. FRAMEWORK AND METHODOLOGY

The National Curriculum Statement (NCS) Grades R−12 and the Curriculum and Assessment Policy Statement (CAPS) of the Department of Basic Education (DBE) (DBE, 2020a) governed the South African public school system for the period under investigation 2014−2018. CAPS provided the programme and promotion requirements. All the examination papers for the National Senior Certificate (NSC) examinations from 2008 are available on the website of the DBE referenced above.

The Grade 12 DBE mathematics examination papers of five years 2014−2018 were analysed together with all the examination papers for the following period (ten semesters) of the BCom mathematics-based modules DSC1520 and DSC1630 presented by our department. For the analysis, a qualitative research approach was used by means of a content analysis (Marsh & White, 2006) of the papers. We used our knowledge and experience as university lecturers of more than twenty years each, as bases for the analytical constructs. Together with the content analysis, the Revised Bloom's Taxonomy (RBT) for Mathematics (Anderson *et al.,* 2001) provided the framework for determining the level of relative cognitive complexity of the questions in the examination papers under consideration. In a recent paper, Radmehr and Drake (2019) studied the literature and compared the frameworks and major theories being used to inform not only the assessment of mathematics, but also the teaching and learning thereof. They concluded that "RBT seems to be the most detailed, comprehensive and flexible framework, thus providing researchers with the most potential for exploring the teaching, learning and assessment of mathematics" (Radmehr & Drake, 2019: 896) and although it has not been used frequently in mathematics to date, "given its broad range of potential applications, and how flexibly it can be used, we believe it has the potential to be used more widely for mathematics" (Radmehr & Drake, 2019: 916).

The levels of the Revised Bloom's Taxonomy for Mathematics are displayed in Figure 2 below and the actions required shown in Table 1. The levels of remembering and understanding are grouped as knowledge and proposed to constitute 20% of a school examination paper. Applying is classified as a routine procedure and accounts for approximately 35% of the examination paper. These three levels of the RBT form part of lower-order thinking. Analysing is classified as a complex procedure and could count 30%. Evaluating and creating are classified as problem solving in Mathematics and could make up the rest of a paper counting 15%. Questions classified as analysing, evaluating or creating are considered higher order thinking skills.

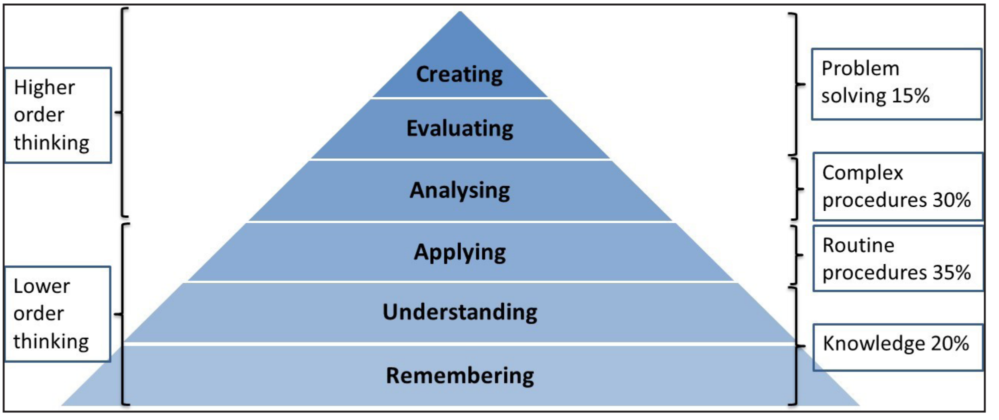


Figure 2: Revised Bloom's Taxonomy for Mathematics (Anderson *et al.,* 2001).

Table 1: Term and actions guide for Bloom's Revised Taxonomy for Mathematics

Term	Explanation	Actions
Remembering	Find or remember information	List, Find, Name, Identify, Locate, Describe, Memorise, Define
Understanding	Understanding and making sense of information	Interpret, Summarise, Explain, Infer, Paraphrase, Discuss
Applying	Use information in new (but similar) situations	Diagram, Make Charts, Draw, Apply, Solve, Calculate
Analysing	Take information apart and explore relationships	Categorise, Examine, Compare/Contrast, Organise
Evaluating	Critically examine information and make judgements	Judge, Test, Critique, Defend, Criticise
Creating	Create something new using information	Design, Build, Construct, Plan, Produce, Devise, Invent

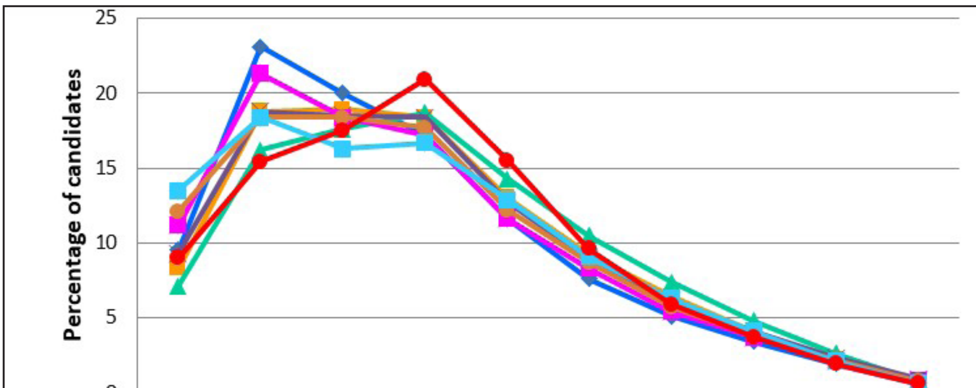
In addition to the examination papers, the Department of Basic Education (DBE) publishes a National Senior Certificate Examinations Diagnostic Report annually (DBE, 2020b). These annual reports present among other aspects, comparative performance data, curriculum topics covered and diagnostic question analyses including comments on the interpretation of the questions. This information was used in conjunction with our content and RBT analyses.

6. RESULTS AND DISCUSSION

We present some interpretation and discussion together with the results because of the nature of the data and the framework used.

6.1 DBE diagnostic reports

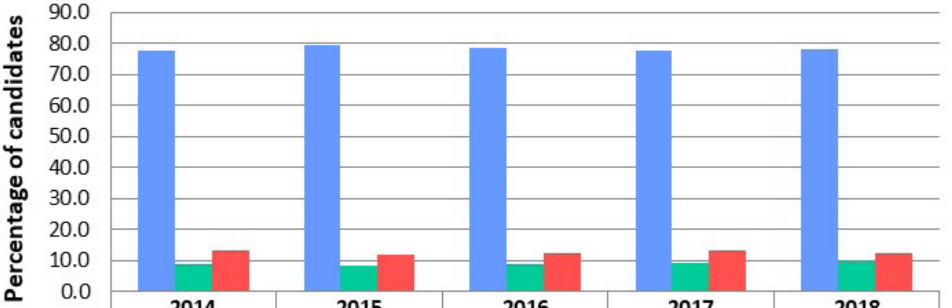
Unisa students do not always proceed directly from Grade 12 to university. But given that we serve almost a third of the country's students, we assume that those who enrol with us, would constitute a reasonable representative sample of the country's Grade 12 population eligible for higher education studies. Figure 3 below depicts the overall performance in Grade 12 Mathematics as extracted from the diagnostic reports after the November examination session of each year. Data were included from 2011 to observe any trend changes that might have occurred moving from the previous curriculum to the current CAPS version, especially during the 2012−2014 implementation phase. There seems to be no significant change that should be reported; in fact, the 2014 data for example seems virtually the same as that of 2012. One could observe that the maximum of the data shifted from the 10−19% range in 2011 to 30−39% in 2018, but that does not alter the fact that the vast majority of learners (78%) still performed below the 50% level seven years later.



	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-100
2011	9.5	23.1	20	17.2	11.6	7.6	5.1	3.4	1.9	0.6
2012	8.3	18.8	18.9	18.4	13	9.2	6.4	4.1	2.2	0.7
2013	7.1	16.2	17.6	18.7	14.3	10.5	7.4	4.8	2.6	0.8
2014	9.3	18.8	18.5	18.4	12.7	8.9	6.1	4.1	2.3	0.9
2015	11.2	21.3	18.4	17.2	11.6	8.3	5.4	3.7	2.1	0.8
2016	12.1	18.4	18.4	17.7	12.2	8.7	5.7	3.8	2.2	0.8
2017	13.5	18.4	16.3	16.7	12.9	9.1	6.3	4.1	2.1	0.6
2018	9	15.4	17.5	20.9	15.5	9.6	5.9	3.7	1.9	0.6

Figure 3: Overall performance (percentage of candidates as a function of their marks) in Grade 12 Mathematics from 2011−2018 (DBE, 2020b).

The percentages of candidates with performance that would allow them directly into the BCom (>59%), extended BCom (50–59%) and Higher Certificate (<50%) for 2013−2018 are displayed in Figure 4. The graph confirms that more than 75% of the candidates have marks less than 50%. This explains the high student numbers in the Higher Certificate in Economic and Management Sciences. On average only 12.6% of the candidates have a final mark of 60% and above. Most of these candidates apply at residential universities first and those that end up at Unisa are usually financially challenged, could not get in elsewhere or are more mature persons that need to work full-time and study part-time through distance education (Subotzky & Prinsloo, 2011).



	2014	2015	2016	2017	2018
<50	77.7	79.7	78.8	77.8	78.3
50-59.9	8.9	8.3	8.7	9.1	9.6
≥60	13.4	12.0	12.5	13.1	12.1

Figure 4: Grade 12 Mathematics performance for three groups from 2014−2018.

6.2 Grade 12 examination paper content

The CAPS Grades 10−12 Mathematics policy stipulates assessment in Section 4 of the document (DBE, 2011). It gives a clear but fixed breakdown for the marks distribution of the Grade 12 end-of-year papers (Table 2). From the papers analysed it seems that examiners within the limits, strictly adhered to the guidelines. The result would be standardisation and the content of papers becoming quite predictable from year to year.

Table 2: Grade 12 Papers 1 and 2 marks distribution out of a total of 150 per paper

Topic	CAPS mark
Paper 1:	
Equations, Inequalities, Algebraic Manipulation	25±3
Number Patterns and Sequences	25±3
Functions and Graphs	35±3
Finance	15±3
Calculus (differential)	35±3
Probability, Counting Principles	15±3
Paper 2:	
Data Handling	20±3

The percentage distributions of prescribed main topics covered in Paper 1 and Paper 2 for the years 2014−2018 are illustrated in Figure 5. This figure shows that the topic Functions and Graphs and the topic Calculus usually each count most of the total paper marks at the 22−25% level. Equations, Inequalities and Algebraic Manipulations count between 14% and 17% of the total marks, with Finance and Probability and Counting Principles around 10%.

Number Patterns and Sequences account for the final 15−20% but are not topics directly used in the first year of Unisa studies.

Paper 2 data is also shown in Figure 5 for the four main topics. The first topic on Data Handling and the other three on Geometry and Trigonometry. For our purposes we focused on Data Handling only and observed that it accounts for approximately 13% of this paper.

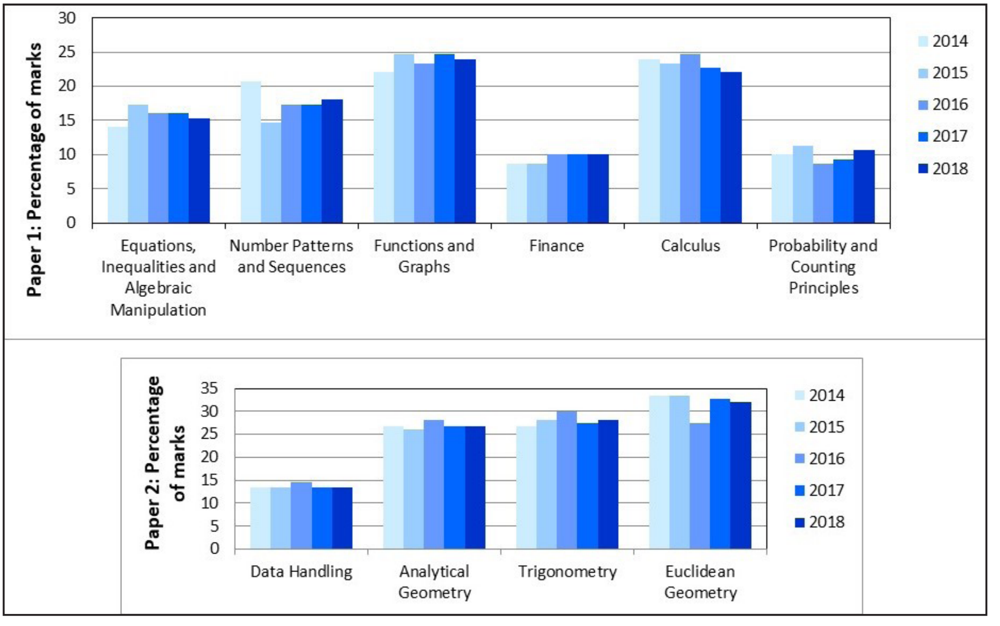


Figure 5: Percentage of marks for topics in Mathematics Papers 1 and 2 from 2014−2018.

6.3 Decision Sciences (DS) modules and paper content

Quantitative Modelling DSC1520 is the mathematics-based first-year module offered in the majority of the Unisa BCom degrees. Introductory Financial Mathematics DSC1630 is part of selected BCom degrees and of the BCompt degree as required by the South African Institute for Chartered Accountants (SAICA) for accounting degrees. Students registered for DSC1630 must also register for DSC1520, but not vice versa. The syllabi of these modules are summarised in Tables 3 and 4.

Table 3: Quantitative Modelling DSC1520 topics

Topic no	Name	Contents
R1	Preliminaries	Arithmetic operations, fractions, solving equations, currency conversions, percentages
R2	Linear Functions	Straight line, Mathematical modelling (graphs), Applications: demand, supply, cost, revenue, elasticity of demand, income
R3	Linear Algebra	Solving simultaneous linear equations, Equilibrium and break-even: Equilibrium in goods and labour markets, Break-even analysis, Consumer and producer surplus, Linear programming
R4	Non-linear Algebra	Quadratic, cubic and other polynomial functions, Exponential functions, Logarithmic functions, Simple Inequalities, Hyperbolic functions *a*/(*bx*+*c*)

Topic no	Name	Contents
R5	Introductory Calculus	Slope of a curve and differentiation, Applications: marginal functions, Optimisation of functions of one variable, point elasticity of demand and the derivative, integration as the reverse of differentiation, power rule of integration

Table 4: Introductory Financial Mathematics DSC1630 topics

Topic no	Name	Contents
S1	Simple and Discount Interest	Simple interest, simple discount, time value of money
S2	Compound Interest	Nominal rates, effective rates , odd period calculations, fractional and continuous compounding, equation of value
S3	Annuities	Ordinary annuities, annuities due, deferred annuities, perpetuities, increasing annuities
S4	Amortisation	Amortisation schedule, sinking fund
S5	Cash flows	Capital budgeting, Internal rate of return, net present value, profitability index, modified internal rate of return
S6	Bonds and debentures	Money market instruments, all-in-price, accrued interest, clean price of a bond
S7	Handling of data	Subscript and summation, arithmetic/weighted mean, standard deviation/variance, linear relationships, correlation and regression analyses

Initially we were looking for the overlap between the Grade 12 Mathematics topics and those in the syllabi of the two BCom modules DSC1520 and 1630. A summary of the overlap is indicated by the solid blocks in Table 5. The Grade 12 Paper 1 topics Equations, Inequalities and Algebraic Manipulation, Functions and Graphs and Calculus overlap with topics in the syllabus of DSC1520. The Paper 1 topic Finance and Paper 2 topic Data Handling appear in the syllabus of DSC1630. Therefore, there are five topics in total from the Grade 12 Mathematics papers (T1, T3−5 and T7) that are considered to be direct pre-knowledge for the BCom modules.

Table 5: Overlap of Grade 12 Mathematics topics with BCom modules DSC1520 and DSC1630

Grade 12 Mathematics Topics	Topic no.	DSC1520	DSC1630
Paper 1			
Equations, Inequalities, Algebraic Manipulation	T1	■	
Number Patterns and Sequences	T2		
Functions and Graphs	T3	■	
Finance	T4		■
Calculus	T5	■	
Probability and Counting Principles	T6		
Paper 2			
Data Handling	T7		■
Analytical Geometry	T8		
Trigonometry	T9		
Euclidean Geometry	T10		

6.4 Revised Bloom's Taxonomy and Grade 12 Papers 1 and 2

The questions for the 2014−2018 Grade 12 Mathematics Paper 1 were classified according to the six RBT levels shown in Figure 2, namely Remembering, Understanding, Applying, Analysing, Evaluating or Creating. The information displayed in the diagnostic reports from the DBE together with the paper memorandums were used in assisting us to clarify ambiguities among ourselves while analysing the questions. The resulting percentage distribution of the RBT analysis is given in Figure 6. It followed that the classifications Applying and Analysing, which account for approximately 70% of the total. During 2017 and 2018 Applying counted for more than 50% of the marks. Except for the 2014 paper, Evaluating counted for between 13% and 18%, which is in line with the proposed Department of Basic Education (DBE) 15% for this level. In all instances, Remembering and Understanding accounted for less than 20% of the marks. Our observation is that for these years, although the highest RBT level Creating was not actually tested, Paper 1 was set to comply with the percentages set by the DBE for the various levels of cognitive complexity.

Data Handling is covered by questions 1 and 2 in each of the Papers 2 of the years 2014−2018. We only classified the Data Handling questions according to the RBT, because the Geometry and Trigonometry questions following in the remainder of the papers are not applicable to the syllabi of the BCom modules. The percentage distribution of the Bloom levels for Data Handling is shown at the bottom of Figure 6. The percentages for each category are not consistent as for the questions in Paper 1 and vary as much as 20% to 60% for the Understanding category. Variations of 20%−40% were found for Remembering and Applying. None of the questions could be classified as either Evaluating or Creating. Data Handling questions seem to be focused on a high percentage of lower level thinking skills, which could mainly be classified as Remembering and Understanding. Aspects of statistics are fairly new to the national curriculum as part of Mathematics, they are introduced to learners towards the latter part of the academic year and counts for only 7% of the final examination mark. These could be contributing factors to the nature of the data presented in Figure 6.

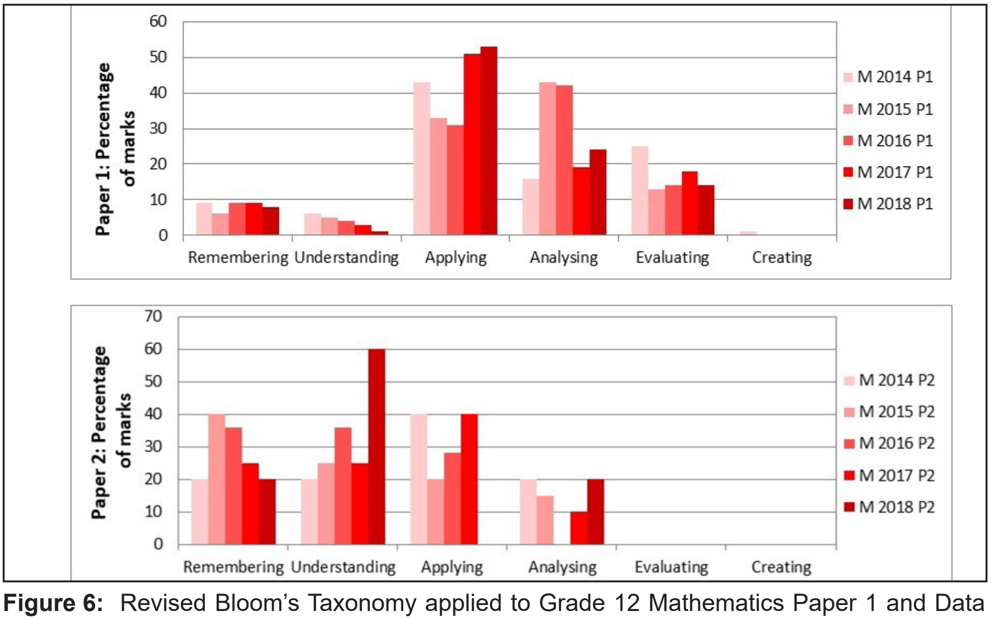


Figure 6: Revised Bloom's Taxonomy applied to Grade 12 Mathematics Paper 1 and Data Handling of Paper 2.

6.5 Revised Bloom's Taxonomy and first level BCom papers

The RBT was also used to classify the May/June Semester 1 and October/November Semester 2, examination questions of the modules DSC1520 and DSC1630 for the years 2015−2019. These years follow on the 2014−2018 period selected for the school papers. Because of large student numbers, between 1 000 to 10 000 during a given semester, these examination papers consist of 30 multiple-choice questions only. Each question of each examination paper was inspected to determine the topic and classify it according to the chosen taxonomy. The percentages based on the RBT classification for DSC1520 and DSC1630 examination papers from 2015−2019 are given in Figure 7 for the same period.

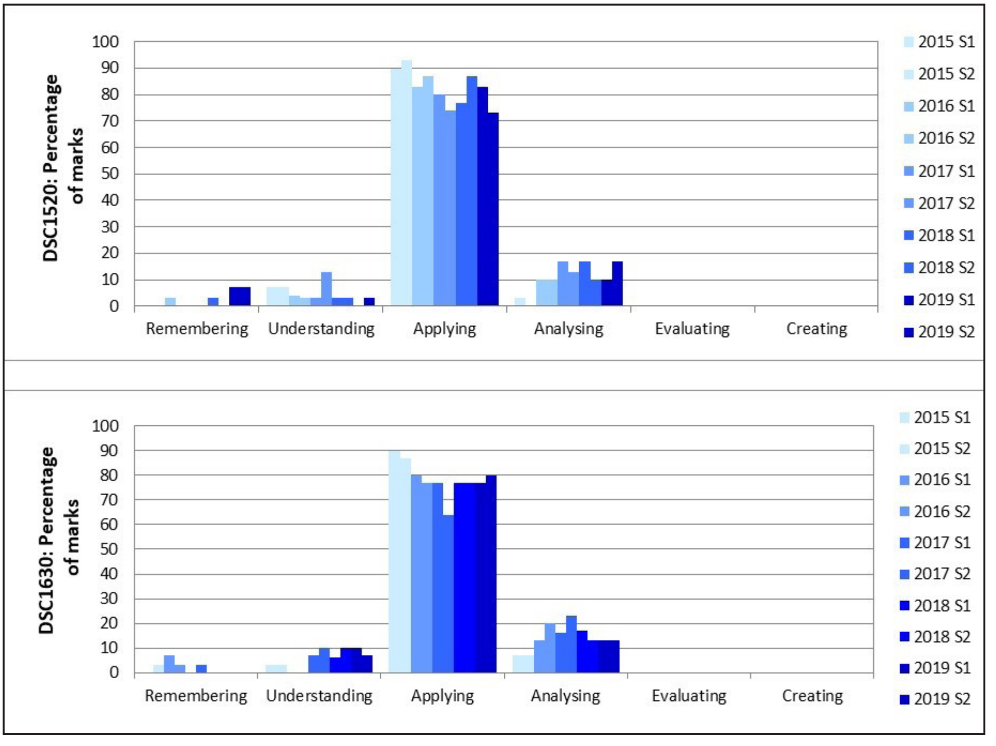


Figure 7: Revised Bloom's Taxonomy applied to DSC1520 and DSC1630 examination questions from 2015−2019.

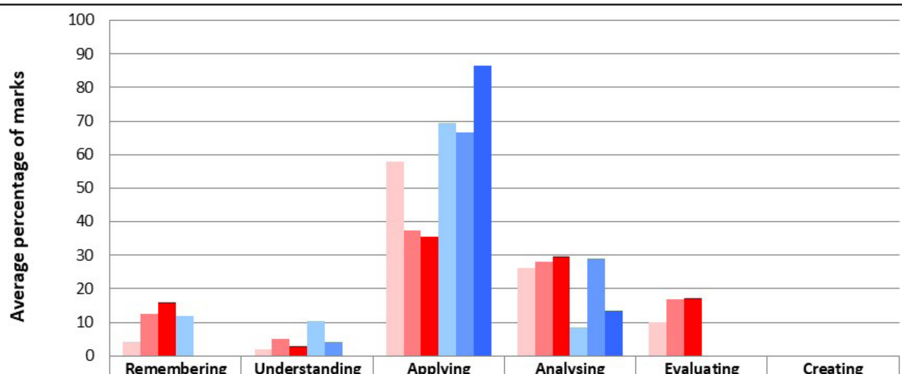
For module DSC1520 questions classified as Applying dominate the examination paper with percentages varying from 73% to 93%. Questions classified as Analysing vary between 10% and 17%. Less than 10% of the questions could be classified as Remembering and Understanding, with no questions on the problem-solving level, Evaluating and Creating. The content of this module consists of mathematical techniques applied to Business, mainly Economics, and that could be the reason why lecturers setting the papers considered the percentage in the Application category to be high. It should be mentioned that basic applications are presented to students during the first year of study, with problem-solving skills following in the consecutive years.

The pattern is similar for the module DSC1630. The focus is also on questions classified as Applying (77%−90%, except for one semester). Between 7% and 23% of the marks are classified as Analysing, again with no questions on the problem-solving level. As before, 10% or less of the marks are classified as Remembering and Understanding. This module concentrates on the application of techniques in financial mathematics to problems in the business, banking and insurance environments.

The analysis displayed by Figure 7 revealed shortcomings in our first level training of BCom students with almost all testing happening only in the middle of the scope of cognitive levels. It puts a firm question mark behind the effectiveness of our efforts to provide students with skills development opportunities. The results of Figure 7 could be attributed to many factors such as the large student numbers, the limitation of only utilising multiple-choice test items and the student profile. Without any clear indication now, this concern with related aspects need further exploration.

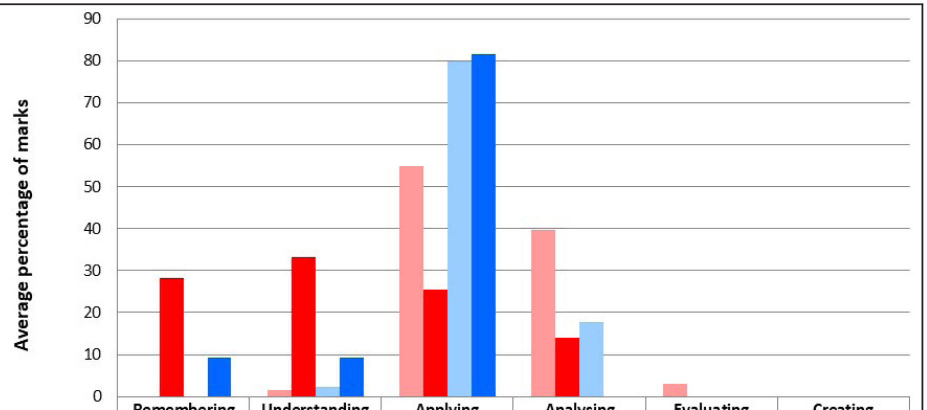
6.6 Comparison of overlapping topics

Next, we focus on the five topics (Table 5) that overlap between the Grade 12 papers and the papers of modules DSC1520 and DSC1630. The RBT classifications for these five topics (T1, T3−5 and T7) were extracted from the data and the five-year average percentages were calculated for each RBT level. The comparisons are displayed in Figures 8 and 9.



	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
Maths P1 Lin Eq	4	2	58	26	10	0
Maths P1 L & NL	13	5	37	28	17	0
Maths P1 Calculus	16	3	35	29	17	0
DSC1520 R2	12	10	69	9	0	0
DSC1520 R3-R4	0	4	67	29	0	0
DSC1520 R5	0	0	87	13	0	0

Figure 8: The RBT five-year average percentage of overlapping topics in Mathematics P1 and DSC1520.



	Remembering	Understanding	Applying	Analysing	Evaluating	Creating
Maths P1 Finance	0	2	55	40	3	0
Maths P2 Data H	28	33	25	14	0	0
DSC1630 S1-S3	0	2	80	18	0	0
DSC1630 S7	9	9	82	0	0	0

Figure 9: The RBT five-year average percentage of overlapping topics in Mathematics P1 and P2 and DSC1630.

Considering DSC1520 first (Figure 8), the topic Linear Equations represented four categories of the RBT, Linear and Non-Linear Algebra three categories and Calculus only two. In comparison, the Grade 12 papers covered the Bloom levels up to Evaluating (level 5), with the focus on Applying (level 3), for all three topics. The authors once more noted that the DSC1520 papers did not test any of the top two RBT levels in contrast to the school papers where there is consistently on average about 16% testing at level 5 Evaluating.

Figure 9 shows the results for DSC1630. The topic Finance T4 in Grade 12 Paper 1 corresponds with the content of the first three topics (S1−S3) in the DSC1630 papers. The school and university papers only tested routine and complex procedures (levels 3 and 4) with the DSC1630 paper having a strong emphasis on Applying at the 80% level. Considering Data handling T7, school and university examiners viewed the topic differently. Although both groups tested basically at the three lowest RBT levels, the school papers showed a similar spread (28%, 33% and 25%) at RBT levels 1 to 3 and 14% at level 4. The DSC1630 papers measured at 9% for levels 1 and 2 and again very high (82%) for level 3. The results represented here could be a topic for further investigation, because it seems that both education sectors steer away from higher order thinking skills when aspects of Statistics, in this instance Data Handling, are examined. Results for DSC1630 are similar to those recently found for assessments in accounting textbooks by Ngwenya and Arek-Bawa (2020).

6.7 Skills required for non-overlapping topics

The two university modules DSC1520 and DSC1630 introduce students to new concepts and ideas related to economics and financial mathematics apart from the overlapping topics with school mathematics already discussed. These include topics such as integral calculus, the natural logarithm, amortisation, bonds and cash flow. The pre-knowledge required to study these non-overlapping topics seems to be covered by the basics of the overlapping topics and simple mathematical techniques learnt at junior high school levels.

7. CONCLUSIONS AND RECOMMENDATIONS

Does the South African school system provide learners with the necessary pre-knowledge and skills to pursue further studies in economic sciences? From the content and RBT investigation of the Grade 12 Mathematics Papers, from 2014−2018, albeit strictly prescribed, it seems a balance has been developed between lower- and higher-order thinking skills. In Paper 1 most of the examination questions could be classified as routine and complex procedures with small percentages indicating knowledge and problem solving on both sides of the spectrum tested. The questions on the topic Data handling in Paper 2 were mostly classified as knowledge and routine procedures at the lower end of the cognitive range. To the contrary, the examination questions on topics of the first level modules for the BCom degrees overlapping with school topics were mostly classified as routine procedures in the university examinations. There was a small percentage on complex procedures, with the remainder based on knowledge. No problem-solving aspects were tested by the examination questions on overlapping topics. Questions probing evaluating and creating skills could have been present in the non-overlapping topics of the syllabi of the modules.

Based on the above, especially the situation with overlapping topics, the answer seems obvious: the students that passed Mathematics at school are supposed to have adequate pre-knowledge for the first level BCom modules. These modules are mostly taken as service modules for BCom and BCompt degrees with specialisation in other disciplines, some not mathematically based. The BCom in Quantitative Management is rooted in mathematics and statistics, but the specialisation only starts at the second level of the degree. In conclusion, there seems to be no glaring gaps in terms of content that should be addressed with learners when they arrive at university for further study. The question remains, why the large dropout rate and failure in university examinations if the school preparation seems suitable? It is accentuated by the fact that the two first level modules did not require students to demonstrate higher order thinking skills in examinations.

Similar to Ireland (Faulkner *et al.,* 2014), South Africa experienced a massification of education, in our case after and because of political changes in 1994. The student profile changed significantly during the period since then and as in Ireland, various pathways have been opened for students to access higher education. This is particularly true for students from lower socio-economic groups. Despite some positive outcomes, the reality as shown in Figure 3 remains that too many learners still fail dismally in mathematics nationally despite well-meant intentions from the National Department of Basic Education. The move from a decentralised system in the nineties to the current seemingly overregulated and standardised national education regime, did not improve the learning experiences of thousands of young people in the country, particularly when it comes to mathematics related skills.

It is concerning and demands attention that our own first level modules, based on this study only, do not seem to provide students with the broad skills set needed to "survive" higher education and become competent economists, bankers, accountants and the like. As elsewhere one of the main reasons behind learning difficulties, seems to be the reduction of complexity compared to procedural focus − "Fundamental competencies such as conceptual understanding and problem-solving ability are not developed by imitative reasoning since it avoids both creativity and meaning" (Lithner, 2011: 295).

The aim of finding solutions for our poor performance in the economic and management sciences, apart from the known challenges of distance education, has already led us to so-called bridging courses and various entry routes as shown in Figure 1. One of the avenues that we could pursue next to get to know our entry students better, would be that of diagnostic testing combined with a more detailed student profile that would also identify students' study needs. We would be supporting an increased emphasis on numeracy in secondary education as well as considering establishing threshold concepts (Houdley *et al.,* 2015) for our courses as a future project to explore the school-university transition in more detail.

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