Trends and targets with respect to NSC results permitting entry into mathematically-oriented programmes at a university

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31 July 2023

This report, produced for the Department of Basic Education, contains background analysis that fed into the Department's 2024 sector review titled 'Review of progress in the basic education sector to 2024: Analysis of key statistics', available at www.education.gov.za (under 'Resources' and then 'Reports'.

This report benefitted from inputs from various analysts at Stellenbosch University's Research on Socio-Economic Policy (RESEP), and underpinned a presentation made by the author at RESEP's 2024 Quantitative Education Research (QER) workshop.

Summary

As part of government's push for improved mathematics outcomes at school, five-year plans have set targets for the number of Grade 12 learners obtaining 50% and 60% in mathematics, but also physical sciences, in the national examinations. The most recent five-year plan set a target of 35,000 learners achieving 60% in mathematics by 2024, with the same target applicable to physical sciences. Targets for the 2029 end-point of what will be the next five-year plan have not been set yet.

Section 2 of the report examines past and future targets, and their realism in the light of what the schooling system is capable of producing, and in terms of the demand from universities. Government's focus on mark thresholds of 50% and 60% in, above all, mathematics is linked to the fact that these are thresholds that universities commonly use in mathematically-oriented programmes such as engineering, medicine, computer sciences and commerce. In fact, around two-thirds of university entrants are subject to some minimum Grade 12 mathematics mark in the admissions criteria, with thresholds ranging from 60% down to 40% for certain programmes and universities.

The report presents an analysis which has apparently not been undertaken before: breaking down recent university first-time undergraduate students according to the minimum marks they should have achieved, and comparing this to what the schooling system has produced in recent years. The analysis draws from both Grade 12 National Senior Certificate (NSC) microdata and university aggregate statistics made available through the online Higher Education Data Analyzer (HEDA) facility.

The 35,000 target for 2024 is in hindsight a target that was arguably set too low. Firstly, even in the wake of pandemic, the target seems reachable by the schooling system, yet the target was set before the pandemic changed prospects. Secondly, the 35,000 target falls short of what universities were demanding already in 2019, by a considerable margin. Specifically, in 2019 around 43,000 first-year undergraduate students were in programmes that required a 60% pass in mathematics. At the time, there were around 29,000 learners achieving 60% in mathematics, implying a 33% *under*-supply. What is clear is that university programmes requiring a 60%

mathematics mark have allowed learners with a lower level of achievement to enrol, which in turn would contribute to a problematically low ‘throughput’ rate at universities. In recent years, only around 60% of first-time undergraduates have completed their studies within an expected period of time. It is debatable what a more realistic 2024 target would have been. The report argues that in the absence of the pandemic, a target of 60,000 by 2024 would have been feasible, and would have satisfied the demand from universities.

Currently, it is very difficult to estimate the extent to which the pandemic reduced the possibility of reaching future targets. Grade 12 mathematics results have in fact not displayed any major losses from 2020, the first year of the pandemic. However, the Grade 12 examinations, like all examinations of their kind, are poorly suited for gauging system-wide trends with respect to the quality of mathematics. This is not what they were designed to do. The release of the 2023 Grade 9 TIMSS results in 2024 will provide a much better basis for gauging the impact of the pandemic on mathematics at the secondary level.

Turning to the question of a workable 2029 target, the report arrives at a target of 140,000 learners achieving 60% in mathematics, and the same for physical sciences. While this target may at first appear over-ambitious, it is important to bear in mind that the distribution of mathematics skills among learners at school is such that the country is reaching a point where the desired increases become almost inevitable, assuming the *average* level of mathematics performance continues to improve as it has for some two decades. This critical point is explained in some depth.

Yet the proposed target of 140,000 is made tentatively, and could serve as a point of departure for the necessary discussions. The report provides evidence that could be used to raise this target above 140,000, and arguments that would favour a lower target. The 140,000 target does not take into account the pandemic, and this could be a reason for lowering it. Moreover, it could be argued that universities will not need this many youths with a 60% mark in mathematics, especially given budgetary constraints that limit the ability of universities to increase their annual intake. Arguments for raising the target above 140,000 would include the fact that thresholds such as 60% are simply a *minimum*, and that more learners above these minima are needed, in part to improve survival to graduation. A further important argument for raising the target is that the number of 18-year-olds in the population is set to increase considerably, by 23% between 2021 and 2027, due to changes in birth patterns almost twenty years ago. This means that in the coming years there will be more youths from which to draw high-level achievers.

Section 3 of the report turns to how the schooling system can advance the aims of the Employment Equity Act. It confirms what has been seen previously, namely that white and Indian youths are over four times as likely to achieve 60% in mathematics in Grade 12, compared to black African and coloured (BAC) youths. The denominator here is *youths*, not just examination candidates. This is important, given that not everyone gets to be an examination candidate. The stark inequalities explain why much of the analysis in the report focusses specifically on black African and coloured candidates.

With regard to gender, high-level achievement in Grade 12 mathematics has until recently been one of the few areas in the schooling system where males have out-performed females. However, this pattern appears to be shifting. In 2022, for the first, there were as many female as male achievers of a 60% mathematics mark. The patterns in the data thus suggest there is a relatively high *potential* to reach the Employment Equity Act aims of gender representativity in the workplace. However, across-race inequalities in mathematics performance are clearly one key barrier to achieving the race-based representativity across occupations envisaged by the Act.

Section 4 of the report examines patterns in the NSC data with a view to identifying pockets of excellence, and parts of the system where better performance could be expected with respect to high-level mathematics achievement. The intention is to inform the debate on how to address the under-supply of mathematics skills, above all by improving the chances among black African and coloured youths of achieving a 60% mathematics mark in the NSC examinations.

With regard to pockets of excellence, it is striking that the provinces Limpopo and Mpumalanga emerge as particularly good performers when 60% mathematics achievers over the youth population (of any race) are considered[1]. This is despite the fact that these provinces do not fare well with respect to the widely used pass rate, or NSC graduates over examination *candidates.* This underscores the limitations of using the pass rate as a gauge of provincial performance. The relatively good performance of Limpopo and Mpumalanga emerges even more prominently when just black African and coloured youths are considered.

With respect to *schools* serving as pockets of excellence, Limpopo emerges as the province with proportionally the highest number of schools which consistently produce 30 or more black African or coloured 60% mathematics achievers[2]. 'Elite' schools defined in this manner are important. To illustrate, nationwide the best 16% of public schools account for half of all BAC 60% mathematics achievers in public schools. After Limpopo, Eastern Cape and Western Cape emerge as strong provinces with respect to the proportion of schools which consistently produce 30 or more high-level BAC achievers. Gauteng's performance in this regard is low, although it should be easier for this province to perform well, given that its schools are the largest in the country, and large schools should find it easier to reach the 30-achiever threshold.

Contrary to what is sometimes believed, schools in socio-economically advantaged areas, particularly suburbs, do not account for most black 60% mathematics achievers. The data indicate that relatively disadvantaged township and rural schools account for three times as many BAC high-level mathematics achievers as more advantaged suburban schools[3].

The 13% of secondary schools which consistently produce *no* black African or coloured 60% achievers in mathematics should be a special concern (here 'consistent' means no such achievers in 2019 or 2022). The worst provinces in this regard are Western Cape and Northern Cape, where over a quarter of schools did not produce any of these BAC achievers[4]. Despite Western Cape faring well in terms of schools with 30 or more 60% achievers, mathematics performance in this province is relatively concentrated in a few schools. Gauteng, on the other hand, has almost no schools producing *zero* high-level BAC achievers over time. Gauteng's performance is more equally spread across schools.

In terms of 60% mathematics achievers over youths, counting just black African and coloured, Limpopo, and to an increasing extent Mpumalanga, are the top ranked provinces[5]. What explains this? Conceivably, it is both the effectiveness of mathematics teaching in schools, and socio-economic factors which lie behind this. With regard to the latter, especially limited opportunities for employment could keep learners longer in school. Could the disappointing statistics for Gauteng and especially Western Cape be explained by the fact that youths are instead achieving high-level mathematics competencies in TVET colleges? Analysis of age data suggests this is not a major explanation. A possible explanation is that the higher proportion of historically advantaged youths in these provinces, whose scores in mathematics would tend to

[1] Figure 26.
[2] Table 10.
[3] Table 7.
[4] Table 10.
[5] Figure 27 and Figure 28.

be relatively high, and the infrequency with which breakdowns of results by race occur, conceal the relative under-performance of black African and coloured learners in these two provinces.

A comparison of Grade 9 TIMSS results and Grade 12 mathematics performance seems to confirm that Gauteng and Western Cape should perform better in Grade 12, and should achieve this through improving outcomes for BAC learners. To gain a sense of the social cost of the inequalities highlighted in the report, if the probability for black African and coloured youths of achieving 60% in mathematics was as good across all provinces as it is in Limpopo, the grand total, across all races, of 60% mathematics achievers would rise by around 11,000, or 33%. Greater competition between provinces to raise the chances of high-level mathematics achievement among black African and coloured learners seems important.

In order to verify patterns seen using aggregates, learners turning 15 in 2018 were linked at the individual level to subsequent NSC data. This analysis confirmed the relatively high success rates of Limpopo and Mpumalanga[6]. It is telling that in these two provinces high-level mathematics achievers are most likely to have repeated a grade in a recent year[7]. This suggests that schools in these provinces use grade repetition judiciously to incentivise better mathematics performance, while ensuring that repeaters are not discouraged and drop out. The linking of individual learners across the two datasets moreover confirms that the findings discussed above are not unduly influenced by across-province migration during the years immediately prior to Grade 12.

An analysis of the consistency of marks across five commonly taken non-language subjects, including mathematics, confirms that results, specifically in the vicinity of a mark of 60%, are internally consistent across subjects within each province. The patterns indicate that mathematics-specific provincial irregularities in, for instance, the marking process do not compromise the comparability across provinces of mathematic results. In particular, there is nothing to suggest that the finding that Limpopo and Mpumalanga are relatively successful provinces is due to some measurement irregularity[8].

[6] Table 6 and Figure 31.
[7] Table 11.
[8] Figure 20 and Figure 21.

Contents

1 Introduction

Improving outcomes in mathematics in schools is emphasised across many policy documents. At the continental level, the African Union's Continental Education Strategy for Africa (CESA) states the following (italics added)[9]:

> The relevance of secondary education remains a concern as it relates to employability, technical and vocational training and articulation with tertiary education. *Math and science at this level are critical to the development of a well-equipped human capital* capable of competing in increasingly science and technology driven world as well as the foundation for knowledge-based economies.

South Africa's National Development Plan (NDP) prioritises mathematics outcomes[10], while the 2019 to 2024 five-year plan of government, the Medium Term Strategic Framework (MTSF), pays special attention to the number of Grade 12 learners obtaining at least 60% in mathematics in the final examination[11]. The importance of this indicator, and a similar indicator for physical sciences, is emphasised in the 2023/24 Annual Performance Plan of the Department of Basic Education (DBE).

The emphasis on mathematics represents a broader interest in strengthening subjects with a mathematical orientation, including physical sciences, life sciences, computer applications technology, business economics and accounting. Mathematics is a fundamental pillar for these other subjects.

There are several ways of measuring progress with respect to mathematics outcomes. Easily the most reliable measures the system has are those drawing from the international TIMSS[12] programme, which has monitored mathematics at the lower secondary level since 1995. This source points to relatively rapid improvements since 2002[13], though even in the latest TIMSS run, of 2019, South Africa still emerged as a weak performer among middle income countries. The problem is, firstly, that South Africa's point of departure two decades ago was very low and, secondly, that across the world the speed of improvements, where they occur, tend to be

[9] African Union, 2016: 18.
[10] National Planning Commission, 2012: 305.
[11] Department of Planning, Monitoring and Evaluation, 2021: 58.
[12] Trends in International Mathematics and Science Study.
[13] Department of Basic Education, 2023: 13.

slow, according to historical data. The latter 'inconvenient truth' is largely related to the difficulty of changing practices across the vast teacher workforce.

Grade 12 examination results are also often used to gauge progress in mathematics. This can lead to inaccurate trends given problems such as selection effects (the selection of learners who take the mathematics examinations changes over time), changes in mathematics topics covered, and limitations with respect to mark standardisation[14]. These problems have been relatively serious in mathematics, leading to confusion around whether mathematics is improving or not. Clearly, the TIMSS Grade 9 trends point to the schooling system becoming better at equipping learners with mathematical skills, and it can thus be assumed that mathematics in Grade 12 is improving too.

Around 60% of youths currently get to participate in the National Senior Certificate (NSC) examinations. Of this 60%, around 40% take mathematics, as opposed to mathematical literacy. This means only around 25% of youths get to write the mathematics examination. Of these, only around 55% pass mathematics at the basic 30% pass level, meaning only some 13% of youths pass mathematics. Finally, extremely few youths get to obtain a mark of 60% and above – only around 3% of youths do this. The implications of this, and how to improve this figure, are the focus of the current report.

The low pass rate in Grade 12 mathematics – the aforementioned 55% – raises the question of whether fewer learners should take mathematics, as opposed to mathematical literacy, while preparedness for mathematics is as weak as it is. This is a complex matter. There is some evidence that at least one province, Gauteng, raised the numbers of learners with high mathematics marks by reducing the total number of learners permitted to take mathematics[15].

Another area of confusion relates to what the critical mark thresholds in mathematics are. The basic 30% pass mark has implications for a learner's attainment of the NSC. However, where universities require a certain level of performance in mathematics, thresholds used are in the range of 40% to 60%. The NDP's proposal that by 2030 450,000 Grade 12 learners qualify for mathematically-oriented Bachelors studies at a university is clearly over-ambitious and based on the incorrect assumption that a mark of 30% is satisfactory for such studies[16]. The NDP's target here would be ambitious even for a developed country. At the same time, while a focus on learners achieving distinctions, or 80% and above, in mathematics and other subjects is popular, it should be noted that such a threshold lies *above* any of the entrance requirements of universities.

The MTSF envisages the number of Grade 12 learners obtaining a mark of at least 60% in mathematics increasing from 28,000 in 2018 to 35,000 in 2024[17]. In 2022 the actual figure stood at 33,815, making attainment of the 2024 target quite possible[18]. This report discusses what the targets beyond 2024 should be, considering both what the schooling system is capable of producing, and what the demands of universities and the labour market are.

The MTSF also envisages 35,000 learners attaining at least 60% in physical sciences by 2024. Physical sciences also receives attention in the report, but it will also be made clear why monitoring mathematics should be prioritised.

[14] Department of Basic Education, 2023: 18.
[15] Gustafsson and Taylor, 2018.
[16] National Planning Commission, 2012: 305.
[17] The 2014 to 2019 five-year plan focussed instead on learners achieving 50% in mathematics – see Presidency (2014).
[18] Department of Basic Education, 2023: 19.

Section 2 focusses on a feasible target for 2029, for both mathematics and physical sciences, drawing from an analysis of what universities demand and likely trends in the supply of mathematics in the coming years. Section 3 examines inequalities in the acquisition of mathematics skills across population group (or race) and gender, and considers these in the light of the Employment Equity Act's goals of a more demographically representative workforce. Section 4 examines the variations in mathematics outcomes across provinces, districts and schools in order to identify pockets of exceptionally good or weak performance, and thereby opportunities or improvements. This section moreover examines whether patterns in the data suggest provincial responsibilities during, for instance, the examinations marking process affect the comparability of results across provinces, and finds this not to be the case.

2 Realistic targets for high-level mathematics achievement in the NSC

2.1 An analysis departing from what universities *demand*

This section focusses on what levels of mathematics achievement in Grade 12 are required to sustain the *current* patterns of intake into universities, as well what is likely to be required in future. This is an important analytical exercise which seems not to have been undertaken previously.

Statistics available through the Higher Education Data Analyzer (HEDA) portal[19] were used to produce the first three columns of statistics in Table 1 below. The methodology used to analyse the statistics is explained in detail in Appendix A. Essentially, a sufficient sample of universities and study specialisations was selected and actual entry requirements for these programmes available on the websites of universities were consulted. Percentages in Table 1, which reflect the pre-pandemic 2019 situation, are weighted by number of first-time undergraduate students aged 18 to 34, where 'undergraduate' refers to students in degree, diploma and certificate programmes. To illustrate how Table 1 should be read, around 33% of first-time undergraduates are not subject to any mathematics entry requirements, meaning 67% are. No instances were found where a physical sciences threshold applied, but no mathematics threshold. Requirements can be ranked, from the lowest, where a 40% mark in mathematics is required while there is no physical sciences requirement, to the highest, where a 60% mark is required in both mathematics and physical sciences. In these two categories, 13% and 10% respectively of all first-time undergraduates can be found. A further 43% of undergraduates are subject to requirements situated between the lowest and highest categories. In total, 27% of undergraduates were required to have 60% in mathematics (see '60-X').

The second column extrapolates from the sample and total first-time undergraduate numbers, and reflects how many students are subject to each requirement. It is clear that the number of first-time students who should have achieved at least 60% in mathematics, 43,265, exceeds the number who have actually reached this level of performance in mathematics in recent years – the maximum annual value across the years 2017 to 2022 is 34,451 Grade 12 candidates, and in 2018 the number was 29,174 (reflected in the Table 1)[20]. Notably, the 43,265 demand figure in Table 1 also exceeds the 35,000 *target* for 2024 set in the MTSF, suggesting the target was set too low.

[19] www.heda.co.za.

[20] Department of Basic Education, 2023: 19.

Table 1: Demand and supply of high-level mathematics outcomes 2018-2019

Combinations of mathematics and physical sciences thresholds	% of first-time undergraduates	Extrapolated first-time undergraduates 2019		Actual NSC graduates 2018		Surplus (B – A)
		Numbers	Numbers cumulative (A)	Numbers	Numbers cumulative (B)	
0-0	33	54,081				
40-0	13	21,633	108,163	42,426	96,517	-11,646
50-0	17	27,041	86,530	10,161	54,091	-32,439
50-50	10	16,224	59,489	14,756	43,930	-15,559
60-0	10	16,224	43,265	3,330	29,174	-14,091
60-40	3	5,408	27,041	673	25,844	-1,197
60-50	3	5,408	21,633	2,988	25,171	3,538
60-60	10	16,224	16,224	22,183	22,183	5,959
60-X	27	43,265		29,174		
Any math. threshold	67	108,163		96,517		
Total	100	162,244				

Sources: Own analysis of PowerHEDA aggregated data for universities, and 2018 microdata on full-time NSC candidates.
Note: Due to rounding, some values may not add up precisely. NSC statistics reflect full-time candidates only.

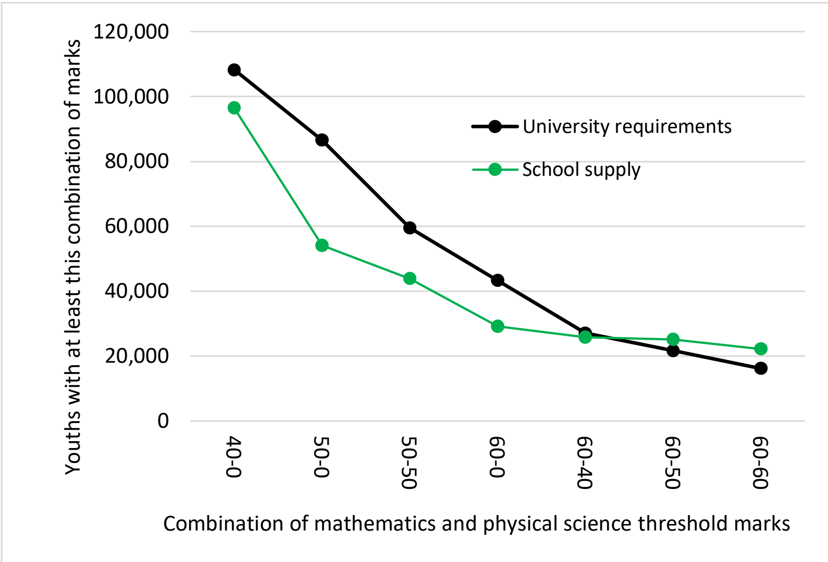
The cumulative values in Table 1, the columns marked A and B, are used for Figure 1 below. Cumulative values were calculated as, for instance, anyone with 60% in both mathematics and physical sciences would be eligible for *any* programme, including a programme requiring just 40% in mathematics. Hence 96,517 school-leavers had 40% or more in mathematics. But, as seen in the table, universities required a slightly higher number of 108,164.

If one focusses only on truly well-performing students who had to have 60% in *both* mathematics and physical sciences, then the schooling system produces slightly more than what is needed, assuming of course that *everyone* with this level of achievement from the schooling system goes to university *and* studies something which requires 60% in both subjects. Clearly, this assumption would not hold fully, so the slight over-supply of the schooling system referred to here may in fact not be real. Yet there does not appear to be a very serious under-supply problem at this level. As mentioned earlier, there is an under-supply problem of some 33% if the 60% threshold in mathematics is considered, without considering physical sciences (the aforementioned 29,174 is 33% below 43,265). However, Figure 1 reveals that the greatest under-supply problem is that of school-leavers with at least 50% in mathematics. While the schooling system supplied 54,091 learners with 50% or more in mathematics, universities required this number to be 86,530. Here there is a large under-supply of 37%, or 32,439 individuals. This fact should be emphasised in any initiatives aimed at improving mathematics outcomes. In contrast, the under-supply at the 40% mark threshold in mathematics is a lower 11%. More Grade 12 learners need to achieve 40%, but an especially important challenge is to *ensure that many more of these learners achieve at least 50% and even 60%.*

The NSC statistics referred to above, and in most of the remainder of the report, all draw from data on full-time year-end NSC candidates from the public examination system, of whom there were 752,003 in 2022. This means some 10,000 relatively well-performing candidates from the private systems are excluded. But excluded are also some 30,000 graduates within the public system, including mostly part-time candidates obtaining the NSC and some 6,000 recipients of the equivalent Amended Senior Certificate. The performance of these excluded candidates tends to be weak, according to the available statistics. For instance, in the 2021 year-end examinations, though part-time candidates were slightly more likely to have mathematics as a subject than full-time candidates, only 0.9% of part-time students obtained a percentage mark of 60 or more in mathematics, against 4.7% among full-time students. Moreover, given how few part-time candidates there are, only 1,474 of them obtained 60 or more in mathematics, against 34,451 among full-time candidates. Critically, many part-time candidates are aiming to improve their earlier mathematics mark. Thus, of the 1,474 obtaining 60 or more in 2021, 1,015 took mathematics as full-time candidates in 2020, and in that earlier year 202 obtained 60 or more in mathematics, and the mean score across the 1,015 was 53% in 2020 and 67% in 2021. To illustrate, ignoring part-time candidates would in this example result in 430 candidates being considered to have reached a mark of 50, when in fact they reached 60 on the second attempt.

Further confounding the situation is the fact that full-time candidates can repeat as full-time candidates. For instance, 250 full-time candidates obtained a mark of 60 or more in mathematics in *both* 2020 and 2021. Here the approach of not taking into account repeaters would produce an over-estimate of 250 learners in 2021. Similar patterns would be found even before the pandemic. Not including part-time candidates in the analysis, and ignoring repetition, which is the approach mostly taken in the official year-end NSC reports, is not ideal, but the distortion created by the this appears not to be substantive, and downward biases are to a large degree offset by upward biases. A key reason why the current analysis follows the approach of counting only year-end full-time candidates, and treating them as non-repeaters, is that details on part-time candidates are limited to only a few years in the available data.

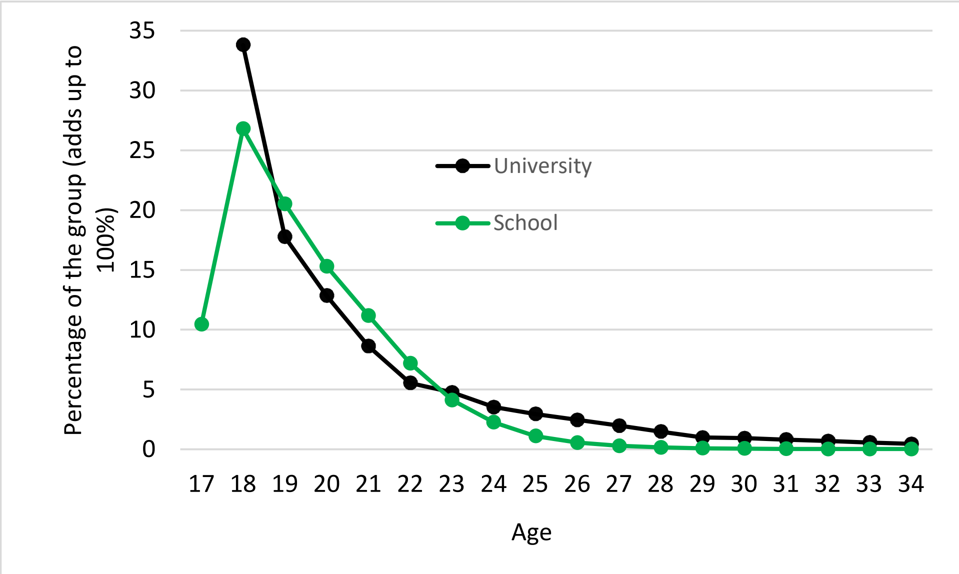
Figure 1: University requirements and school supply 2018-2019



As pointed out in Appendix A, further work could be done to tighten up the values in the first column of Table 1, in particular by expanding the sample. However, as explained in the appendix, the sample appeared large enough to produce stable statistics. One comparability matter worth underlining relates to age. Enrolment at a university appears to occur several years after schooling for many South Africans[21]. This suggests schools should aim to supply not just what is needed by universities in the next year, but also several years into the future, when the demand for skills is likely to be higher. Insofar as this is true, the analysis of Table 1 would *under*-estimate the supply shortfall. However, as can be seen in Figure 2, the age distributions of the 2018 Grade 12 candidates and 2019 first-time undergraduates used for Table 1 are remarkably close. It is to be expected that school-leavers will be at least one year younger than next year's university entrants, and this can be seen in the graph. In short, the school and university numbers largely reflect comparable groups of people in terms of age.

[21] Van der Berg *et al*, 2020: 45.

Figure 2: Age distribution of NSC candidates and first-time undergraduates



There are three critical dimensions the current analysis does not take into account, and this should ideally be included in some way in future, even if rough estimates must be made in the absence of reliable and sufficiently detailed statistics. Firstly, HEDA data (and thus the first two columns of Table 1) exclude private higher education institutions, which account for 22% of non-foreign undergraduate enrolments in degree, diploma and certificate programmes[22] (readily available statistics do not provide first-time undergraduates as a separate category). Secondly, of the public university students represented in Table 1, some 3% are foreign and would therefore in many cases not have obtained a South African school certificate. Thirdly, the supply of learners with the NSC in Table 1 (third-last column) excludes NSCs obtained outside the public system, meaning mostly the Independent Examinations Board (IEB). While IEB candidates only account for 2% of all full-time NSC *candidates* in recent years, the little that the IEB does release in terms of statistics suggests that the IEB may account for some 10% of NSC candidates *obtaining at least 40% in mathematics*[23]. The first of these three exclusions would result in an *under*-estimate of supply shortfalls, while the third exclusion would result in an *over*-estimate. Roughly, and given the magnitude of the private university exclusions, the net effect of the three exclusions can be considered an *under*-estimation of the supply shortfall of around 10%.

What future targets are universities subject to which would influence school targets? There are no targets for first-time undergraduates in general, or per field of study. Less immediately relevant indicators must thus be used. Van der Berg *et al* (2020: xi) examine the targets of the NDP and highlight the following as being especially important:

- University enrolments should increase from around 1,050,000 to 1.6 million between 2019 and 2030, so by 52%, or by 4.8% of the baseline figure annually.

[22] Calculated from Department of Higher Education and Training (2022).

[23] Around 90% of the approximately 13,000 IEB candidates obtained a Bachelors-level pass in 2022. Among Bachelors-level passes in *independent schools* within the public system, 44% came with a mathematics mark of at least 40%. In arriving at the 10% referred to in the narrative, it was assumed that 60% of IEB candidates obtain at least 40% in mathematics. This is almost certainly an under-estimate, given that independent schools writing the IEB examinations school learners from especially advantaged backgrounds.

- The number of first-time university qualifications obtained should increase from around 170,000 in 2019 to 320,000 by 2030, an 88% increase. The increases should be concentrated in mathematically oriented areas such as engineering.

The 2019 to 2024 MTSF envisages the ‘number of graduates in engineering’ increasing annually by 2.8% of the 2019 baseline figure, or an additional 369 graduates a year, up to 2024[24]. Assuming a continuation of this trend, the 2030 number of graduates would be 31% higher than the 2019 number.

The MTSF also refers to the need to increase the ‘throughput’ of each ‘first-time cohort’ of university students from 58% of first-timers in 2014 to 64% of first-timers in 2024. Here throughput essentially means progression through to graduation within a reasonable period of time. This is important for the setting of school targets for a few reasons. On the one hand, if the ‘throughput rate’ improves, then fewer first-time undergraduates are needed to produce a fixed of number of graduates. More importantly, however, the high levels of ‘non-survival’ to graduation imply that it is important for Grade 12 learners not just to reach thresholds set by universities, but to *exceed* them. If some 40% of first-year university students are not ‘surviving’ to graduation, while the size of the gap between the curves in Figure 1 is never more than 37%, this suggests that the thresholds set by universities are a bit too *low*, assuming that it is an inability to cope academically that is largely behind dropping out from universities[25].

Prevailing budget constraints have led to smaller envisaged growth in the university sector than what previous targets suggest. The Estimates of National Expenditure (ENE) of 2023 points to university enrolments increasing between 2019 and 2025 by just 1.0% of the baseline value annually[26]. This is much lower than the 4.8% referred to above.

In short, university enrolment expansion is envisaged to increase annually between 1.0% and around 5.0% in the coming years. This implies that the 108,163 first-time students subject to some mathematics threshold seen in Table 1 would increase to some 120,000 to 160,000 in 2029, depending on what percentage one used. It is perhaps realistic to take a midpoint between these two figures and envisage 140,000 youths reaching at least a 40% achievement level in mathematics in 2029, with many achieving thresholds above this, in some cases also in physical sciences, in line with the first column of Table 1. Specifically, some 110,000 would need to reach at least 50% in mathematics, and some 60,000 would need to reach at least 60% in 2029. These are estimates based on the *demand* from universities. As will be seen in section 2.2 below, estimates based on what the schooling system seems capable of producing point to *higher* possible targets.

University plans for expansion are in part based on information on demand in the labour market. This is beyond the scope of the current report, but it should be mentioned that the Labour Market Intelligence (LMI) programme of the Department of Higher Education and Training (DHET) provides relatively detailed indications to universities, and other post-school institutions, of what skills are required. It is clear that South Africa has a particularly severe skills shortfall: within a group of 38 countries consisting mainly of OECD members, but also five non-OECD developing countries, South Africa has the highest percentage of occupations filled by under-qualified workers[27]. Areas of the labour market with particularly serious skills shortfalls include banking and insurance, and the energy and water sectors, areas which require mathematics, and in some cases physical sciences[28].

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24 Department of Planning, Monitoring and Evaluation, 2021: 65.

25 There is evidence to support this assumption – see for instance Van Broekhuizen (2016).

26 National Treasury, 2023: 284.

27 Vandeweyer and Verhagen, 2022: 10.

28 Kuluvhe *et al*, 2022: 98.

What South Africa, and probably most countries, lack are official numbers of new entrants into specific occupations needed per year, something which should be based on both demand in the economy and attrition and retirement patterns among existing workers. Examples of this can be found in the Occupational Outlook Handbook of the United States Bureau of Labor Statistics, which has for instance the following in relation to civil engineers[29]:

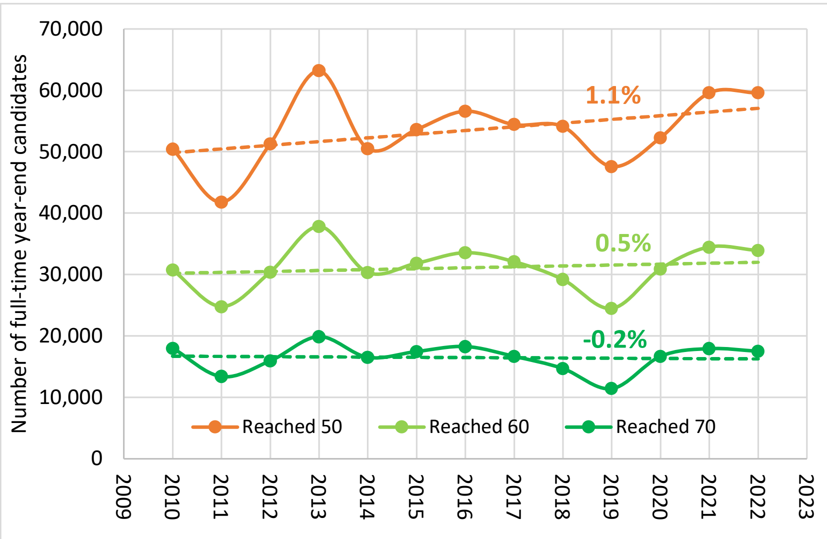
> Employment of civil engineers is projected to grow 7 percent from 2021 to 2031, about as fast as the average for all occupations.
>
> About 24,200 openings for civil engineers are projected each year, on average, over the decade. Many of those openings are expected to result from the need to replace workers who transfer to different occupations or exit the labor force, such as to retire.

2.2 Further details on the *supply* of Grade 12 mathematics skills

This section discusses past trends in mathematics outcomes, and what the current distribution of results implies for the future. In the introduction it was mentioned that officially published mathematics results in Grade 12 can be confusing if taken as an indication of systemic trends. This is because the Grade 12 examinations, like any examinations of their kind, are not suited for the monitoring of trends[30]. The following three graphs should be interpreted in the light of this. Mathematics outputs, in terms of marks, have grown faster at lower levels of achievement, for instance in the mark range of 30% to 39% – see Figure 3. Growth has been worst at the very highest 70% to 100% mark range – see Figure 4. Despite their limitations, marks are clearly important, in part because they function as a barometer of mathematics achievement used to accept or reject students into particular university programmes. As far as possible they should be in line with actual trends in mathematics outcomes. Yet for technical reasons an exact alignment can be considered extremely difficult to achieve, especially given the rapid turnaround time between the writing of the examination and the issuing of certificates with final results.

An important recent feature is the abrupt decline in the number of candidates obtaining a mark of 60 in mathematics in the years 2018 and 2019, in other words just before the pandemic. The 'pandemic years' of 2020 to 2022 saw a return to patterns seen before 2018.

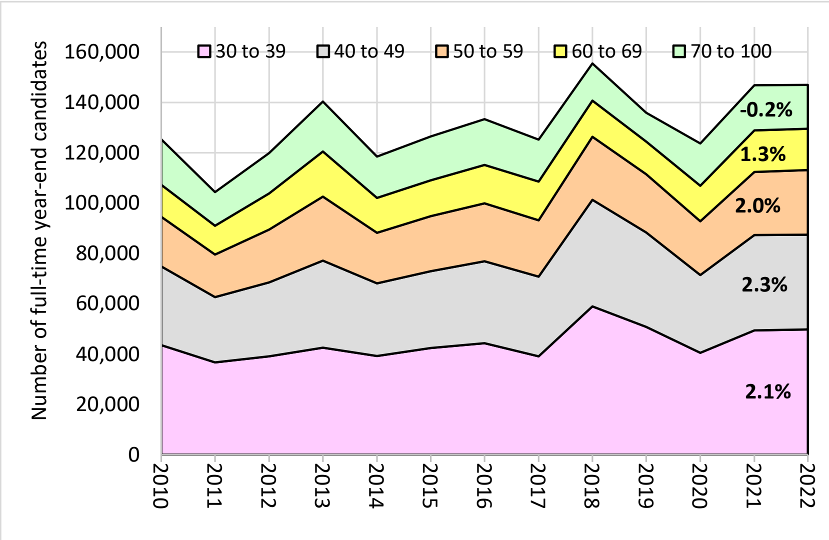
Figure 3: National mathematics trends at three top thresholds



[29] Viewable online through the search tool at www.bls.gov/ooh/home.htm (accessed March 2023).
[30] Apart from sources in this regard provided above, see Professor Shay's (2020) article and responses to this on the same web page by the author of the current report.

Source: In this and the following two graphs, own analysis of NSC full-time candidate microdata.

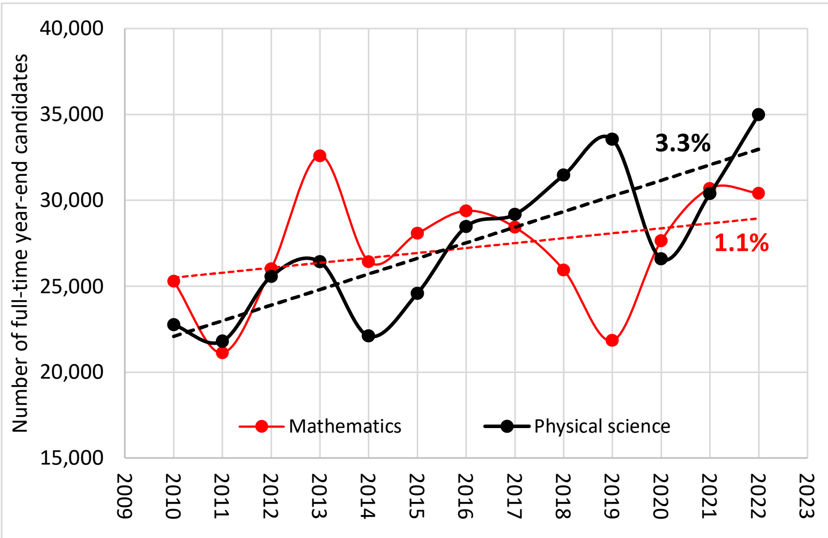
Figure 4: National mathematics trends at five thresholds



Note: Percentages refer to average annual increases (based on the slope). Each percentage refers to the annual growth in just the one segment.

Figure 5 below, which examines only learners taking both mathematics and physical sciences, serves as a reminder of the measurement problem: the speed of improvement in mathematics appears to be a third of that seen in physical sciences. This is despite the fact that the two subjects are strongly interlinked in terms of content. Earlier analysis using a benchmark reference group of demographically stable and high-performing schools has shown that if increasing levels of difficulty in the mathematics examination are taken into account, the mathematics trend essentially follows the physical sciences trend, as one would expect[31].

Figure 5: Comparison against physical sciences for same learners at 60% threshold

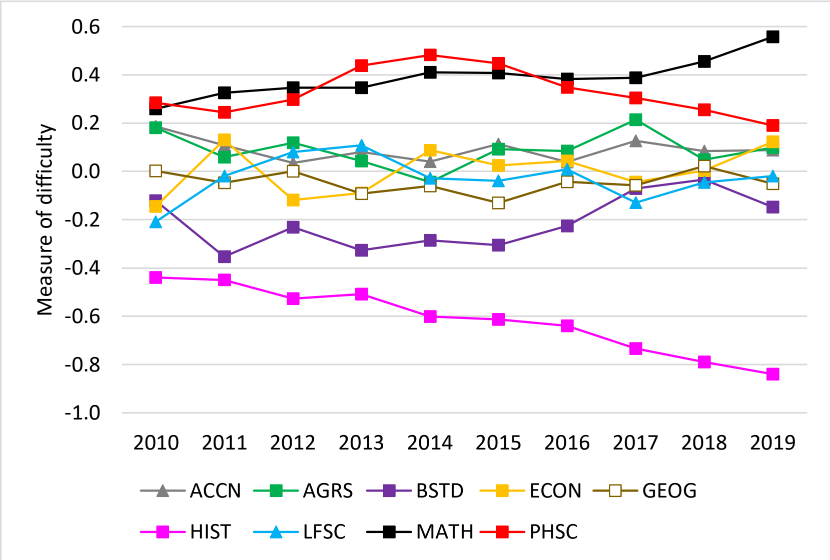


The following graph, taken from an earlier and unpublished DBE report[32], uses a Rasch technique to gauge the difficulty of reaching the 60% mark threshold across nine Grade 12 non-

[31] Gustafsson, 2016.
[32] Gustafsson, 2020.

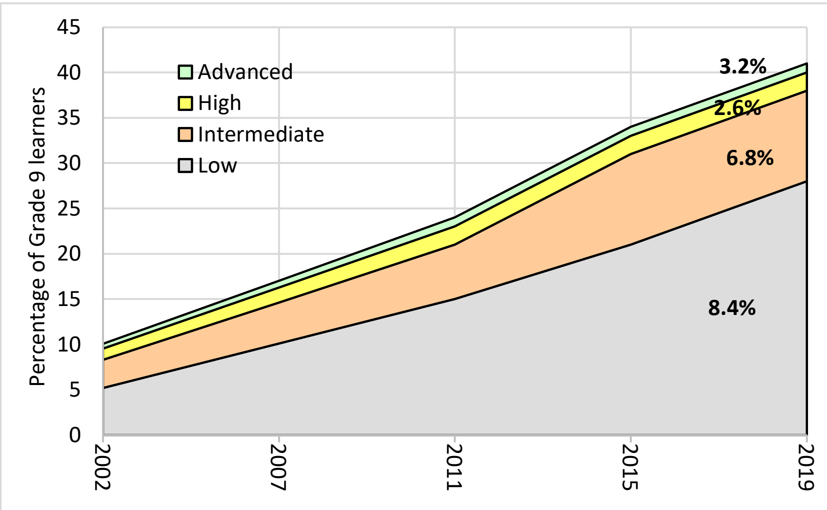
language subjects. This method provides further confirmation that the differences in the slopes of the two subjects seen in Figure 5 are in large part due to the fact that the attainment of relatively high marks in mathematics has become increasingly difficult over time, at least relative to what other subjects have experienced.

Figure 6: Rasch analysis of Grade 12 subject difficulty 2010-2019



The following two graphs reflect the trends in TIMSS Grade 9 relative to the four TIMSS international benchmarks. While the overall patterns seen in TIMSS reflect actual skills among learners more accurately than those in the Grade 12 results, TIMSS is based on a sample and there are therefore confidence intervals around the percentages shown in the two graphs. Between 2002 and 2019, learners reaching at least the high benchmark increased by around 2.8% a year, while the figure for science was a similar 3.5%. As will be seen below, the high benchmark in TIMSS corresponds roughly to a 60% mark achievement in Grade 12, at least for mathematics.

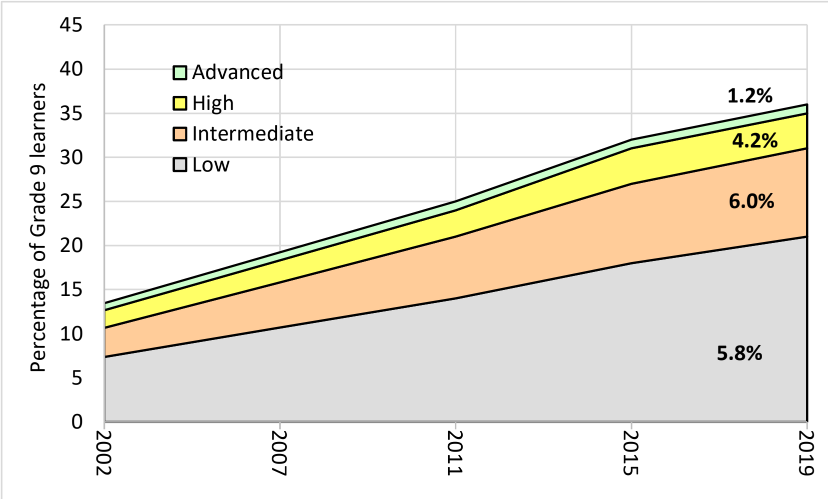
Figure 7: Improvements against TIMSS benchmarks in mathematics



Sources: Mullis et al *(2020) for 2011, 2015 and 2019 values. 2002 values are calculated using the Grade 9 microdata (most published results are for Grade 8 only). For 2007, the mean across 2002 and 2011 was used.*
Note: As in Figure 4, each percentage value on the right refers to the annual growth of that segment. Segments are mutually exclusive. For instance, 'Low'

here is learners achieving the low benchmark score, but not *reaching the intermediate threshold. The following graph follows the same conventions.*

Figure 8: Improvements against TIMSS benchmarks in science



The Grade 9 TIMSS data, as will be seen, provide an invaluable source for understanding future possibilities with respect to Grade 12 mathematics outcomes. The first column of Table 2 below draws from values behind Figure 7. Of all Grade 9 learners, 1% reached the 'advanced' benchmark of 625 TIMSS points in 2019, 3% reached *at least* the 'high' benchmark of 550, and 13% at least the 'intermediate' benchmark of 475. For the last two columns, the total age 18 population was considered[33]. Approximately 3% of this population achieves around 60% in mathematics. The 60% Grade 12 threshold in mathematics can thus be said to correspond to the 'high' benchmark in TIMSS. To estimate how many learners might reach the 60% mark in Grade 12 in future years, one can use a projection of the expected percentage of learners expected to attain the high benchmark in Grade 9.

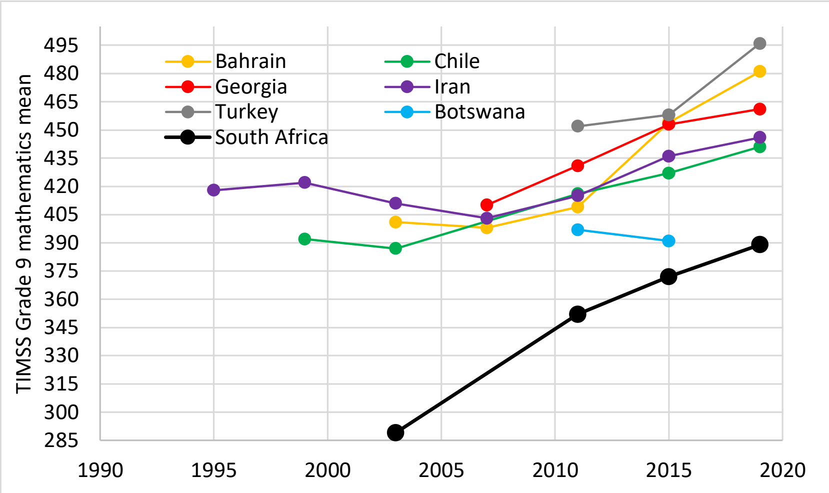
Table 2: TIMSS Grade 9 thresholds in terms of NSC mathematics scores

TIMSS international benchmark	% reaching this in 2019 in South Africa	TIMSS benchmark threshold	Corresponding NSC mathematics mark 2018	2019
Advanced	1	625	77	74
High	3	550	62	60
Intermediate	13	475	38	35

Figure 9 below illustrates a fact often acknowledged, namely that South Africa's Grade 9 mathematics outcomes are improving steeply, albeit off a low base. Of all the curves in the graph, South Africa's has the steepest slope.

[33] Estimates of the age 18 population in Gustafsson (2022) used.

Figure 9: TIMSS grades 8 and 9 mathematics means



Sources: Mullis et al *(2020) and earlier reports in this series. South Africa's 2003 score (actually gauged in 2002 in South Africa) is from Reddy* et al *(2012), with a small upward adjustment applied to take into account the fact that independent schools were excluded from the 2002 Grade 9 sample.*

However, Figure 10 indicates that the achievement of the high benchmark in mathematics has barely changed over time in South Africa. This could lead to the conclusion that South Africa has made the mistake of focussing on improvements at the middle levels, while ignoring the top levels. Such an argument is in fact not justified if the distribution of scores is considered. There is a pattern whereby countries with especially low and especially high *mean* scores in TIMSS see only small changes to the percentage of learners who excel. This is illustrated in Figure 11. Each marker represents a country from Figure 9, with Taiwan added as an eighth country – Taiwan stands out as one of very few countries with a high average score *which is also improving rapidly with respect to its mean score.* As can be seen from the graph, neither South Africa nor Taiwan saw significant increases in the percentage of high-performing learners. This is because the high-performing learners were either at a narrow right-hand tail in the distribution (South Africa), or because learners *below* the high benchmark were at a narrow *left*-hand tail in the distribution (Taiwan). This is illustrated for South Africa in Figure 12[34]. Learners reaching the *low* international benchmark of 400 have increased substantially because the peak of the distribution was reaching a point relatively close to 400. This meant that the curve was steep around the 400-score point, and any shift rightwards in the distribution would produce substantial change. At the high TIMSS benchmark of 550, in contrast, the curves have been flatter, producing a smaller change. This will change in the coming years.

[34] This is an updated version of a graph found in Department of Basic Education (2020: 84).

Figure 10: TIMSS grades 8 and 9 high benchmark achievement

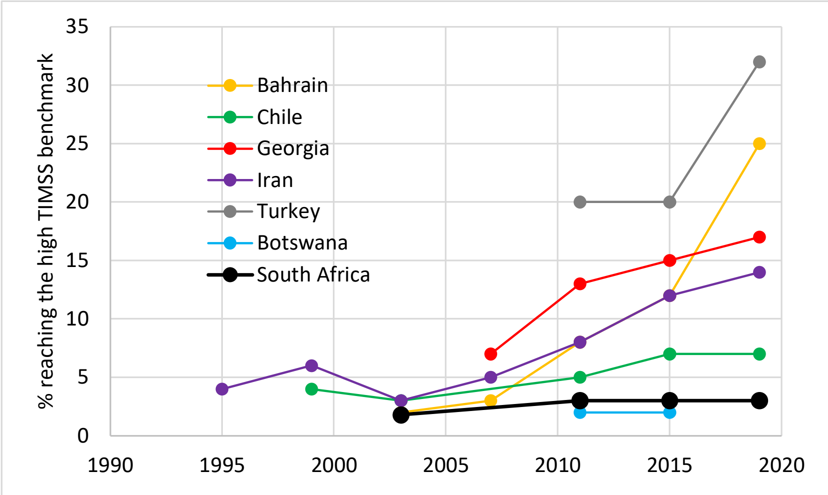
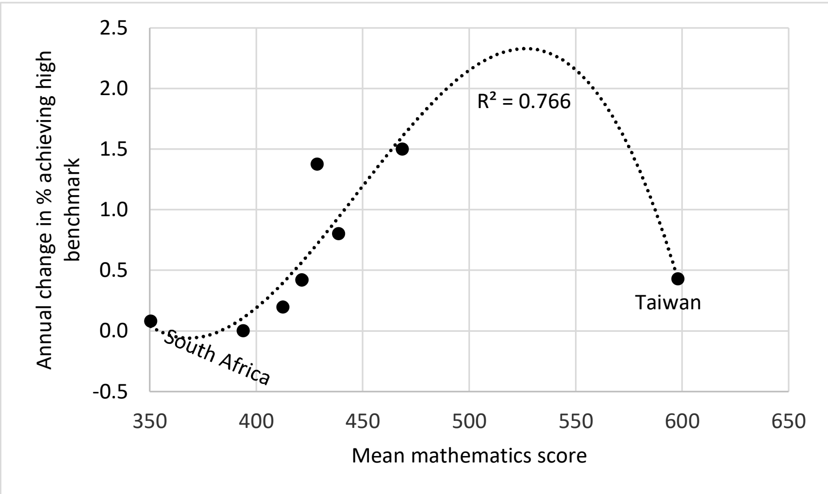
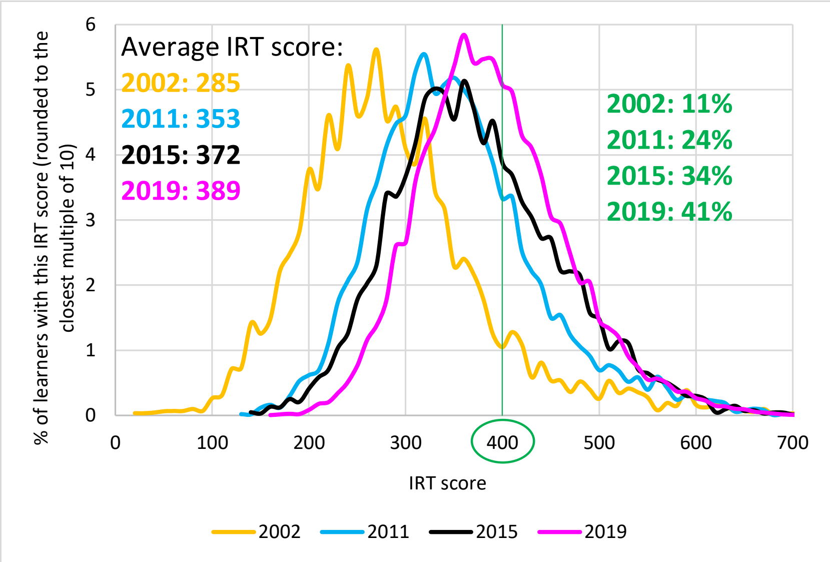


Figure 11: TIMSS mean scores and high-level improvements



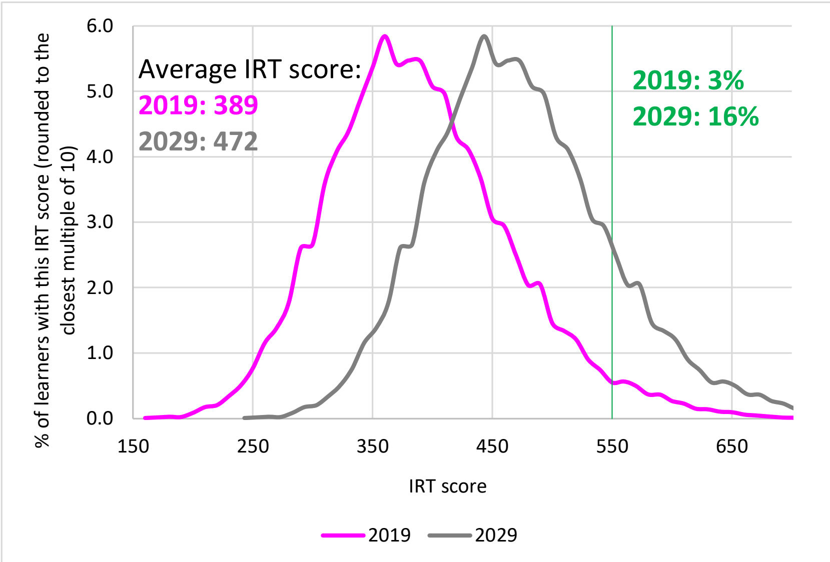
Note: The trendline is a third-order polynomial. Values on the vertical axis use the slopes of the curves from Figure 10. Values on the horizontal axis are the means per country across all years from Figure 9.

Figure 12: Distribution of TIMSS mathematics scores 2002 to 2019



For Figure 13, the 2019 distribution has been shifted to the right, in line with historical trends, to produce an estimated 2029 distribution. In this scenario, the slope of the distribution at the 550-score point *does* become relatively steep, meaning that the percentage of learners reaching the high benchmark level increases substantially. As long as the mean score continues to improve as in the past, and in line with targets already published by the DBE[35], a large increase in high-level mathematics outcomes is almost inevitable. (An important caveat relating to the effects of the COVID-19 pandemic is discussed below.)

Figure 13: Projected TIMSS mathematics distribution in 2029

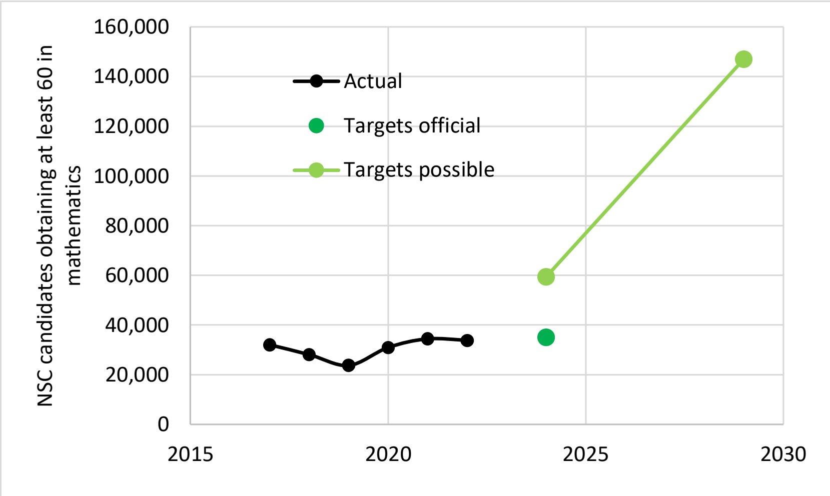


Using the increase in the percentage of youths achieving a 60% mathematics mark from 3% in 2019 to 16% in 2029, translates to the absolute numbers seen in Figure 14 below. The aforementioned official target of 35,000 for 2024 seems low. It is low in terms of historical trends (shown in the graph), in terms of what the schooling system is capable of producing (based on the trend suggested by Figure 13), and in terms of the demand from universities (see section 2.1 above). In retrospect, a target of around 60,000 by 2024 seems justifiable. To be

[35] Mean values of 426 in 2024 and 472 in 2029 are envisaged, in line with Department of Basic Education (2023: 13).

clear, the suggestion is that had the evidence from the schooling system and universities been considered more carefully back in 2019, when the target was set, a target of 60,000 could easily have been justified. The same method used to obtain the 60,000 target value also produces a value of just over 140,000 in 2029.

Figure 14: Actuals and targets to 2029 for mathematics at 60



It is conceivable that the historical 2020 to 2022 values in Figure 15 would have been higher had there not been a pandemic, and if rising difficulty levels in the mathematics examinations had been taken into account in better ways. Higher values for these years would have made the 2024 target of 60,000, which does not take into account the pandemic, more realistic. The 2029 target of just over 140,000 is arguably over-ambitious insofar as it does not consider the negative impacts of the pandemic. However, especially before the TIMSS 2023 results become available, there is hardly any basis for making a pandemic-related adjustment. While there is some literature examining the impacts of the pandemic at the primary level[36], very little work has occurred in this regard at the secondary level. Politically, it could be argued that targets should not be adjusted downwards to take into account the pandemic, because government has a number of initiatives aimed at ensuring the schooling system recovers from the pandemic. In short, it could be argued that a target of 140,000 Grade 12 learners achieving a mark of 60% in mathematics by 2029 is feasible and can be backed up by analysis.

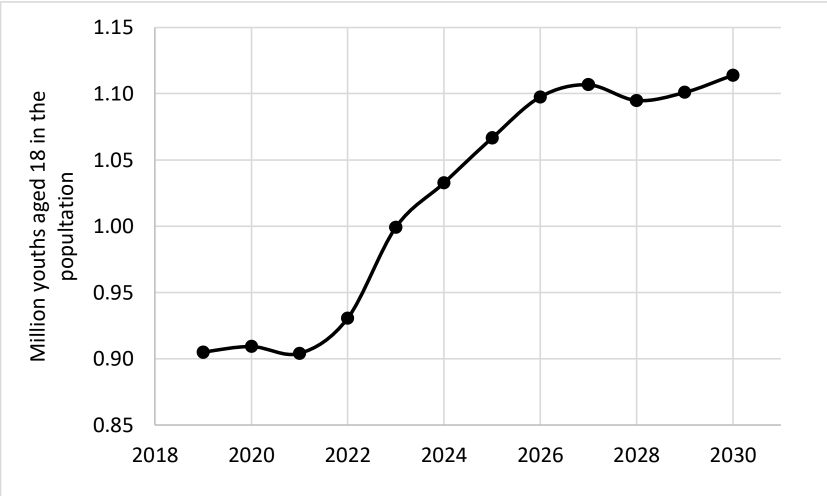
The 140,000 target mentioned here is much higher than the 60,000 youths with a mark of 60% in mathematics required by universities by 2029, according to section 2.1. This suggests that there is not a serious *supply* constraint in the coming years. The schooling system can realistically be expected to meet demand. Is there then a risk of an *over*-supply of mathematical skills among youths? Given that the envisaged TIMSS mathematics mean of 472 by 2029 (Figure 13) is likely to be in line with that of other middle income countries *in 2029* (Figure 9), what is envisaged here does not suggest an over-supply. It should be remembered that the thresholds applied by universities, and discussed in section 2.1, are *minimum* values, and that more achievement above these minimum values is needed to improve ‘throughput’ in universities. In addition, mathematics skills are required among those entering other post-school education and training institutions, particularly the TVET[37] colleges.

A further adjustment to the 140,000 target has not been made. This is an adjustment to deal with population growth. Figure 15 points to the number of eighteen-year-olds being 23% higher in 2030 than 2019. This reflects changes in birth numbers after around 2004. A larger pool of youths should make the 140,000 target easier to achieve. An upward adjustment of the target in

[36] Kotze *et al*, 2022.
[37] Technical and vocational education and training.

line with the population trend may seem technically straightforward. However, there are uncertainties relating to, for instance, the impact of larger classes on mathematics outcomes, and it is therefore not that easy to adjust the 140,000 upwards. Given that the 140,000 target seems to satisfy university demand, it appears useful. To conclude, this target is *too ambitious* insofar as it does not take into account the longer-term effects of the COVID-19 school disruptions, but it is also *not ambitious enough* insofar as it does not take into account the fact that there will be more youths aged 18 in 2029.

Figure 15: Population aged 18 from 2019 to 2030



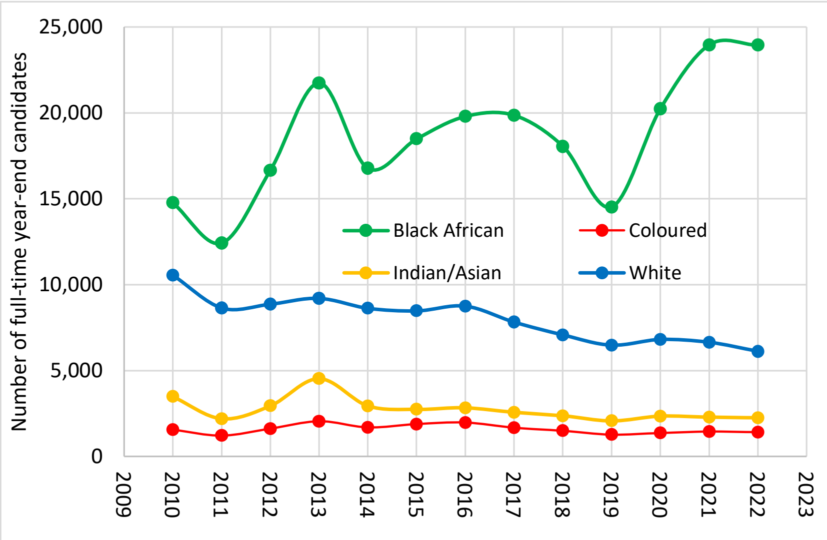
Source: The projections of the Thembisa Project (www.thembisa.org). The version 4.5 projections were used.

Whatever the 2019 mathematics target is, it seems simple and logical to make the target for physical sciences the same, as in the past. The evidence provided above supports such a position.

3 Mathematics outcomes and the Employment Equity Act

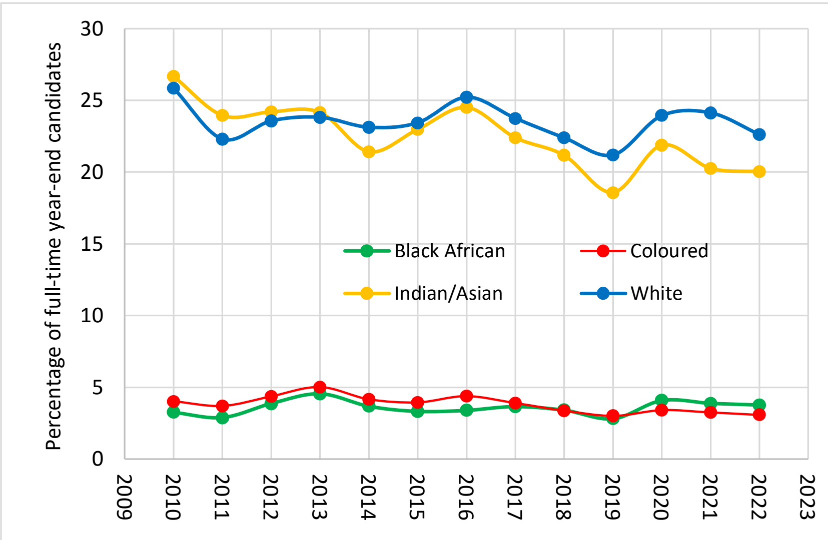
Several policies, but particularly the Employment Equity Act, require occupational skills to become increasingly evenly spread across the country's four population groups and the two sexes. A more representative spread of occupational skills requires the spread of skills in key school subjects such as mathematics to be regularly monitored and improved. Figure 16 below illustrates the number of full-time Grade 12 candidates, by race, achieving 60% in mathematics in the year-end examinations. Most of these candidates are black African, and for this group the trend is clearly an upward one. Yet, as shown in Figure 17, the proportion of *candidates* who obtain 60% in mathematics is lowest for black Africans, and if the proportion of the age 18 youth cohort is considered, the proportion is especially low, at around 4% in recent years – see Figure 18. The proportion of youths is over four times better for whites and Indians. Because coloured participation in the examinations is relatively low, the proportion of *youths* achieving the threshold has been somewhat worse for coloured than black African youths, even if the reverse has been true in some years when *candidates* are considered. Figure 18 essentially emphasises that there is a large inequality gap between, on the one hand, whites and Indians and, on the other, black African and coloured youths. There has been a slight positive trend in the black African curve in Figure 18, but it is so slight that it would take a little over 100 years to catch up with whites and Indians, unless the trend steepened. Of course, this is a simplistic analysis which does not take into account the distributions discussed in section 2.2, which give cause for greater optimism.

Figure 16: Numbers achieving 60% in mathematics, by race



Source: In this and the following three graphs, own analysis of NSC full-time candidate microdata.

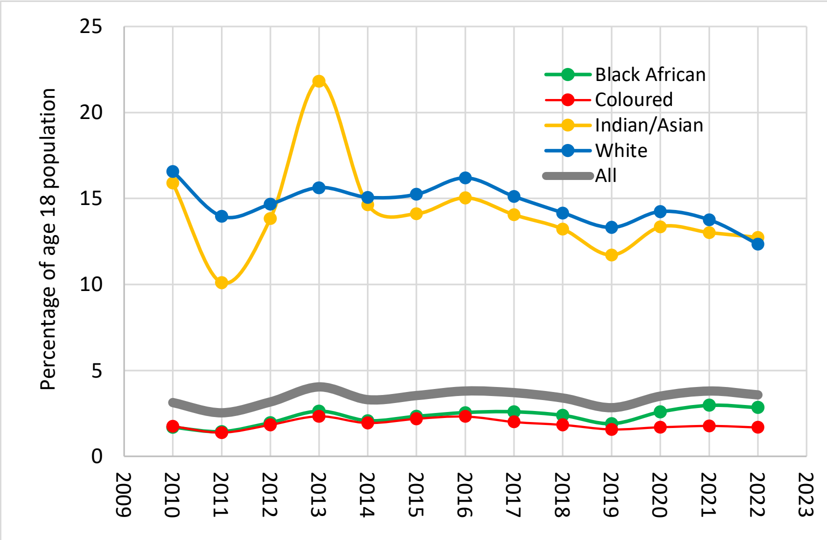
Figure 17: Proportion of candidates with 60% in mathematics, by race



Note: For the denominator in this graph, full-time candidates with a valid mark in the range of 0 to 100 in either mathematics or mathematical literacy were considered.

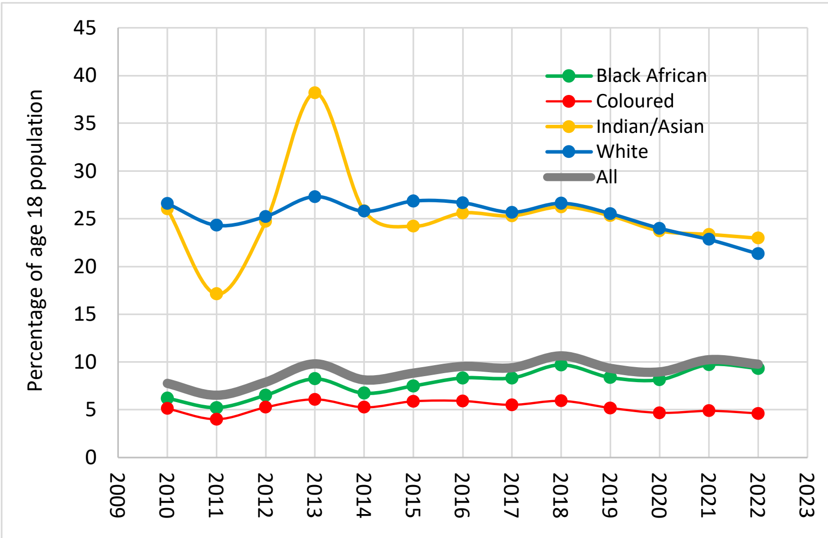
Importantly, the following two graphs display ratios which are probably around 13% too low, because the denominators are 13% to *high* – see the note to Figure 18 below. This means, for instance, that the percentage of one age cohort of youths obtaining 60% in mathematics is not the 3.6% reflected in Figure 18, but rather 4.1%. These issues are important, but they do not alter substantively the narrative around the inequalities.

Figure 18: Proportion of youths with 60% in mathematics, by race



Source: For the denominator, Statistics South Africa published mid-year population estimates (MYPEs) are used, with Stats SA's published Sprague converter to extract just the age 18 population.
Note: Analysis of official enrolment statistics suggest that age 18 values from the MYPEs are around 13% too high, making the values seen in the graph under-estimates by around this 13% margin – see for instance Gustafsson (2012, 2022).

Figure 19: Proportion of youths with 40% in mathematics, by race



The Employment Equity Act requires employers with 50 or more employees to have representativity targets informed by national or provincial demographics, and by sectoral targets set by government. Table 3 provides a rough sense of how Grade 12 outputs compare to the demographics of formal sector employees in each province, and nationally. To illustrate, in Free State there were 1,919 Grade 12 graduates with at least 60% in mathematics. Of these, 73% were black African (with statistics for coloured, Indian and white being 1%, 1% and 25% respectively). There were 790,000 formal sector employees in Free State in the first quarter of 2023, according to Stats SA's May 2023 release of the *Quarterly Labour Force Survey*. Of these employees, 84% were black African. If all high-achieving mathematics achievers in Free State are divided by thousands of employees, a ratio of 2.4 is produced. This is higher than the 2.1 figure for the country as a whole. Across all races, Free State is relatively good at supplying the labour force with mathematics skills. If race-specific ratios are examined, it is clear that

Free State supplies relatively many white and Indian high-level mathematics achievers, compared to the number of employees. The ratio is a lower 2.1 for black Africans. This is a key factor underlying inequality in the workforce. A more equitable system would see the ratios being more similar across races. Using these ratios, which provinces emerge as more and less equal? Free State emerges as particularly unequal, in the sense that the 'M over E' ratio for Indians and whites exceeds the ratio for black African and coloured to an especially large degree. Notably, in Eastern Cape and Limpopo the situation is reversed. The ratios are better for black Africans and coloureds combined than for Indians and whites combined. In Limpopo, for instance, 5% of employees in the labour force are white, but only 3% of high-level mathematics achievers are white. There are several possible explanations for this, among which inter-provincial migration is likely to be an important one.

Table 3: Mathematics output and the labour force by race

Province	Thousand employees in formal sector [*E*]	Breakdown of this by race (A-C-I-W)	2022 NSC-holders with 60% in math. [*M*]	Breakdown of this by race (A-C-I-W)	*M* over *E*	*M* over *E* for just black African	*M* over *E* for black African and coloured	*M* over *E* for Indian and white
EC	1,421	74-9-1-16	3,638	85-3-1-11	2.6	2.9	2.7	1.8
FS	790	84-5-0-11	1,919	73-1-1-25	2.4	2.1	2.0	5.7
GP	4,984	80-2-2-16	7,711	61-3-10-26	1.5	1.2	1.2	3.1
KN	2,594	78-2-17-3	7,245	79-1-16-4	2.8	2.8	2.8	2.8
LP	1,388	94-0-1-5	4,524	96-0-1-3	3.3	3.3	3.3	2.2
MP	1,141	93-0-0-7	3,212	89-0-1-10	2.8	2.7	2.7	4.4
NC	339	48-41-0-11	291	47-19-1-33	0.9	0.8	0.6	2.7
NW	877	87-0-0-13	1,319	76-1-2-21	1.5	1.3	1.3	2.7
WC	2,658	28-47-1-24	4,015	17-24-4-55	1.5	0.9	0.8	3.6
SA	16,192	73-10-4-13	33,874	71-4-7-18	2.1	2.0	1.9	3.1

Source: May 2023 release of Stats SA's Quarterly Labour Force Survey. *The racial composition of the workforce was found using 2021 General Household Survey microdata, as this breakdown does not appear in Stats SA's report.*

Table 4 provides a similar analysis by gender. Across all provinces, the patterns suggest it is easier to reach gender equality targets than racial equality targets. This is because in all provinces the majority of employees are men, while the spread of high-level skills across gender is fairly equal. This does not of course mean that gender equality *has* been achieved in occupations with a mathematical orientation, occupations which tend to come with relatively good earnings. Females with good mathematics results could be kept out of these occupations, for a variety of reasons. Instead, the analysis suggests there is a relatively high *potential* for gender-based equality.

Table 4: Mathematics output and the labour force by gender

Prov-ince	Thousand employees in formal sector [*E*]	Breakdown of this by gender (m-f)	2022 NSC-holders with 60% in math. [*M*]	Breakdown of this by race (m-f)	*M* over *E*	*M* over *E* for males	*M* over *E* for just females
EC	1,421	53-47	3,638	50-50	2.6	2.4	2.7
FS	790	56-44	1,919	50-50	2.4	2.2	2.8
GP	4,984	59-41	7,711	47-53	1.5	1.2	2.0
KN	2,594	56-44	7,245	51-49	2.8	2.5	3.1
LP	1,388	61-39	4,524	52-48	3.3	2.8	4.0
MP	1,141	55-45	3,212	51-49	2.8	2.6	3.1
NC	339	62-38	291	46-54	0.9	0.6	1.2
NW	877	63-37	1,319	49-51	1.5	1.2	2.1
WC	2,658	55-45	4,015	48-52	1.5	1.3	1.7
SA	16,192	57-43	33,874	49-51	2.1	1.8	2.5

Comparing mathematics outputs from the education system to the numbers of employed individuals, as is done above, under-states the inequalities insofar as population groups with the lowest mathematics outcomes also tend to have high unemployment rates. Unemployment figures in 2022 for black Africans was around 37%, for coloureds around 25%, for Indians around 15%, and for whites around 9%[38].

4 Strengths and weaknesses in the system which can inform planning

4.1 How comparable across provinces are Grade 12 mathematics results?

As will be seen below, mathematics results can differ considerably across provinces, even for candidates with similar levels of socio-economic disadvantage. A key question is whether this is all due to the greater effectiveness of certain provincial schooling systems, or whether other factors could be playing a role. Whether provinces assess differently is an obvious question. Umalusi (2023) conducts extensive quality assurance of the examinations process. In general, no major across-province assessment differences are found. Provincial education departments are responsible for several aspects of, for instance, the marking process, though they must follow national guidelines. Umalusi's standardisation process presumably includes some validation of the internal consistency of the marks within each province, though this is not explicitly mentioned in its quality assurance reports.

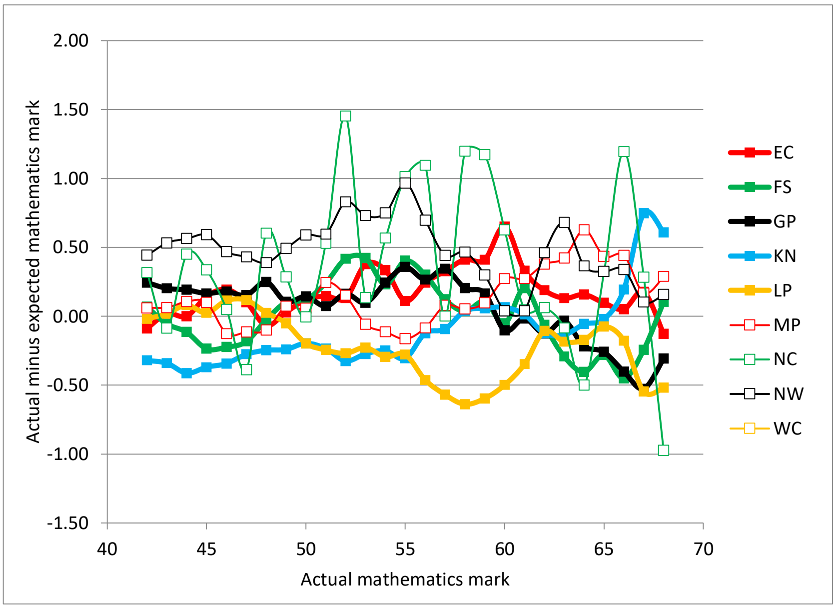
Figure 20 and Figure 21 point strongly to there being no substantive and systematic difference across provinces in achieving, for instance, a mark of 60 in mathematics. In the two graphs, which use examinations data from 2022 and 2019 respectively, the difference between the actual mathematics mark and the predicted mark is shown, at different levels of achievement. The predicted mark is predicted on the basis of four statistics: the mark in English First Additional Language, Life Sciences, Physical Sciences and Geography. This means, for instance, that Figure 20 reflects the results of 27,535 full-time candidates who had marks in the four subjects, plus mathematics, *and* whose mathematics mark was between 40 and 70[39]. The

[38] Stats SA's Quarterly Labour Force Survey report for quarter 1 of 2023.

[39] The predicted score is calculated by first running the following regression on the national data: $M = \beta_0 + \beta_1 E + \beta_2 L + \beta_3 P + \beta_4 G + \beta_5 E^2 + \beta_6 L^2 + \beta_7 P^2 + \beta_8 G^2$. Here M is the predicted mathematics mark of the candidate and E, L, P and G are the candidate's marks in the other subjects. Only candidates with marks 40 to 70 in mathematics are used in the estimation. The predicted mathematics mark is then subtracted from the actual mark. The average difference *nationally* is then found per actual mark. For instance, for candidates in 2022 with an actual mathematics mark of 60 the difference is 5.4, meaning nationally the predicted mark is higher than the actual mark at that achievement level (it tends to be the reverse for levels of achievement below 60). The mean across the differences in Limpopo is

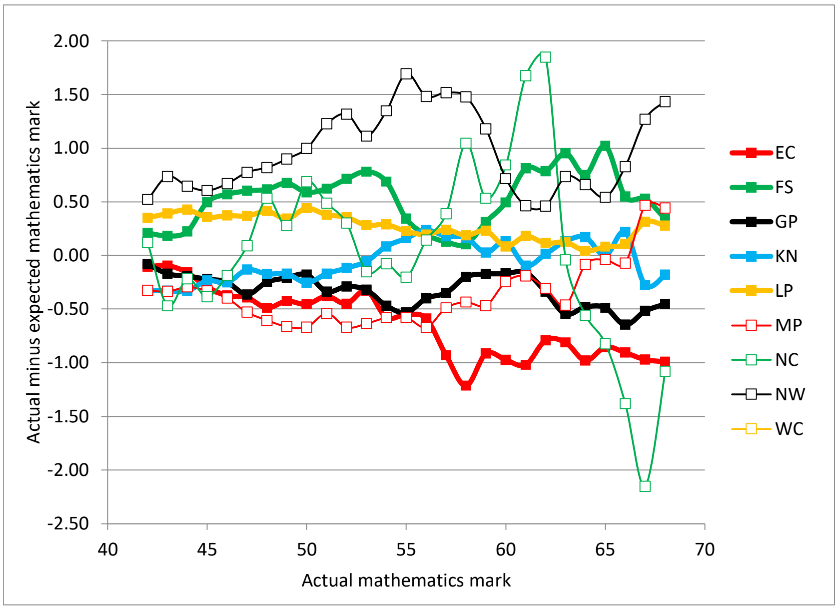
prediction occurred without taking province into account. There are certain patterns within each year which are province-specific, but these patterns change from one year to another. For instance, for Limpopo candidates obtaining an actual mark in mathematics of between 55 and 60, the predicted marks where a bit higher than the actual mark. But the difference was small, only around 0.5 marks. This could be caused by many factors: the kinds of candidates who choose to take mathematics in Limpopo; how well the different subjects used for the analysis are taught in Limpopo, and how Limpopo markers mark the mathematics examination scripts. Comparing the two graphs reveals that patterns change substantially. For instance, in Limpopo predicted scores were *not* higher than actual scores in 2019. Analysis of a few other years confirmed that patterns change from one year to another. There thus appear to be no entrenched and systematic provincial biases in, for instance, how difficult it is to obtain a mathematics mark of 60. If there are biases, they would have to apply across all the subjects to which mathematics was compared here, a problem which seems less likely than the possibility of a bias in a high-stakes single subject such as mathematics.

Figure 20: Predicted and actual mathematics marks compared 2022



5.1, meaning that the difference is smaller for Limpopo than for the country as a whole. 5.1 minus 5.4 gives minus 0.3, which is the value behind the Limpopo curve in Figure 20, for actual mark 60. The curves in the graphs have been smoothed by using running averages that include two values to the left and to the right, so five values in total.

Figure 21: Predicted and actual mathematics marks compared 2019

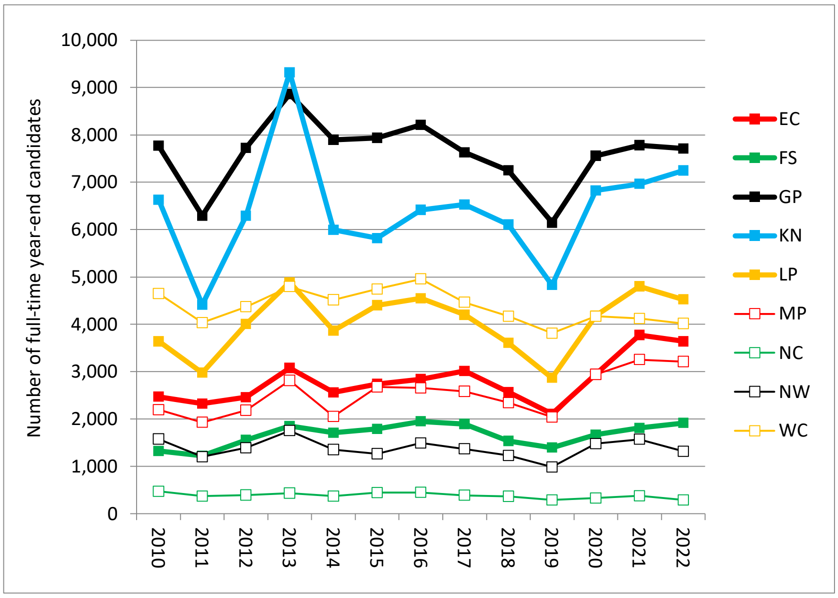


What can be concluded from the analysis is that, for instance, the exceptionally good performance in Limpopo with respect to mathematics, discussed below, is not due to mathematics being assessed differently in that province. In the case of Limpopo, exceptional achievement appears to be a reality, not the result of measurement error.

4.2 Achievement statistics across provinces

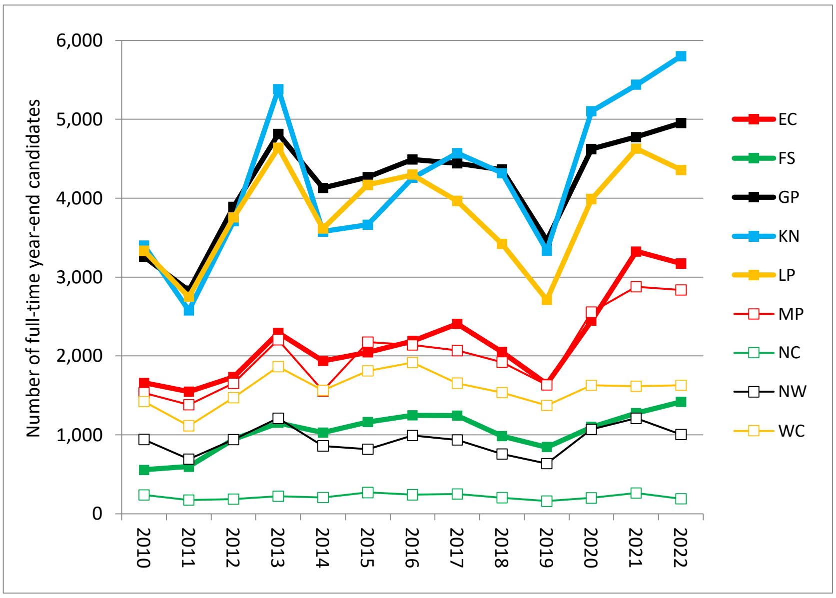
Figure 22 illustrates the importance of the two populous provinces Gauteng and KwaZulu-Natal as sources for youths achieving at least 60% in mathematics. These two provinces accounted for 44% of all such youths in 2022. The 2018 to 2019 dip seen in the graph was briefly discussed in relation to earlier Figure 3.

Figure 22: Numbers achieving 60% in mathematics, by province



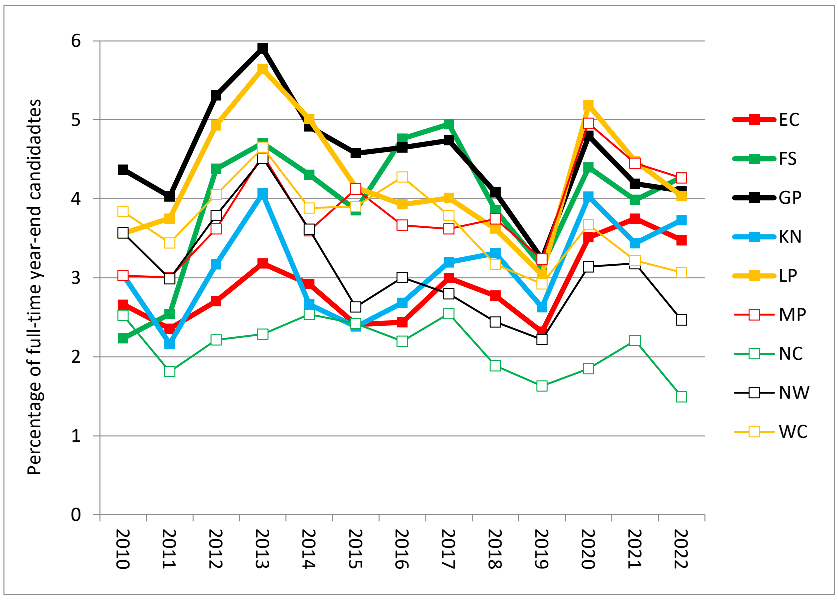
Given the importance of raising mathematics performance among black African and coloured youths – see for instance Figure 18 – much of the analysis that follows focusses just on these two population groups, for which the acronym 'BAC' is used. Figure 23 shows that three provinces are particularly large sources of black African and coloured youths with at least 60% in mathematics: KwaZulu-Natal, Gauteng, and Limpopo. In 2022, these three provinces accounted for 60% of these youths.

Figure 23: Numbers achieving 60% in mathematics, by province (BAC learners)



Relative to Grade 12 BAC examination candidates, Western Cape and Gauteng stand out as strong suppliers of high-level mathematics skills. This can be seen from Figure 24. However, these patterns can be deceptive as they say nothing about youths who leave the schooling system before Grade 12.

Figure 24: Proportion of BAC candidates with 60% in mathematics, by province



Note: Denominator calculated as for Figure 17.

The patterns for achievement of a 40% mark among BAC candidates, seen in Figure 25 below, are similar to the patterns seen in the previous graph. One key difference is that Free State's ranking improves rather noticeably if a 40% mark threshold is used.

Figure 25: Proportion of BAC candidates with 40% in mathematics, by province

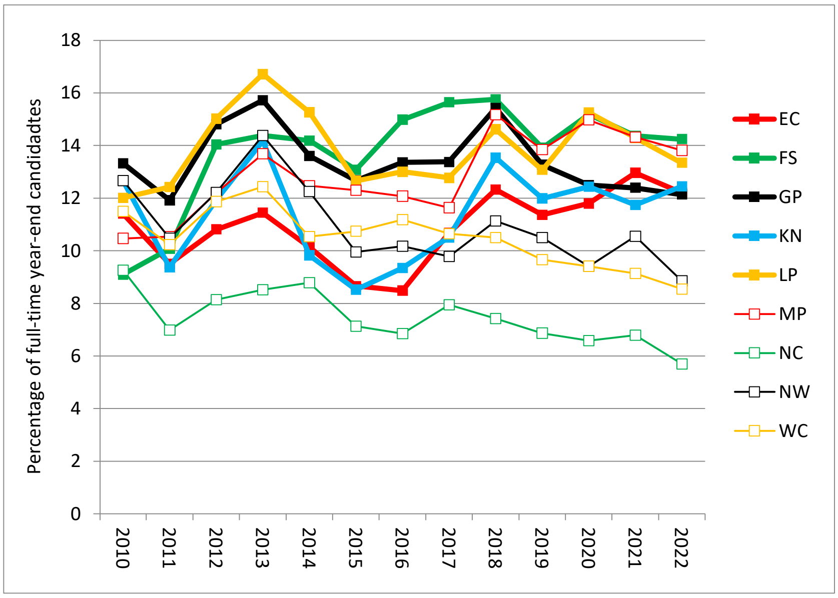


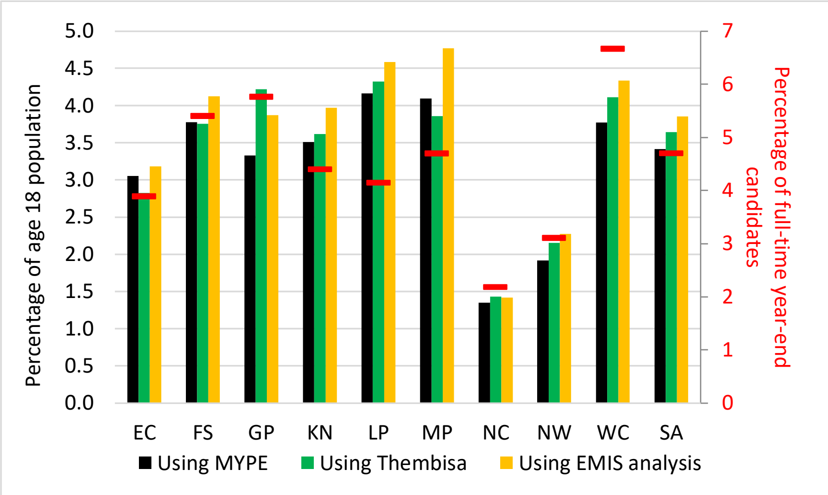
Figure 27 below is critical for gauging the relative success of provinces. Here candidates and youths across all population groups are considered. The ratio of high-level mathematics achievers to one age cohort in the youth is important as it takes into account survival to Grade 12 in a manner that the previous four graphs do not. Figure 27 controls for the strong possibility that some provinces may be especially active in discouraging academically weak learners to enter Grade 12, or that in some province external factors such as poverty depress academic results and hence exacerbate dropping out. The red markers in the graph reflect the 2022 ratio of mathematics achievers with 60% over all candidates. This does *not* take into account survival to Grade 12. Limpopo's value, at 4.0%, is below the national average of 4.7% (markers should be read against the *right*-hand vertical axis). However, when viewed against the youth population, Limpopo fares the best, or almost the best, among all provinces, depending on what measure of the youth population is used. Three measures are represented in the graph. The Stats SA mid-year population estimates (MYPEs) have been used, as in Figure 18. Secondly, estimates by the Thembisa initiative are used[40]. Lastly, EMIS[41] enrolment data were used to identify earlier enrolment of age 14 in order to arrive at a 2022 estimate of the age 18 population (virtually all children aged 14 are enrolled in school, though this is not true of age 18)[42]. Arguably, the third of these three options is the most accurate, as statistics are based entirely on actual counts of people, within a dataset that is now considered to be relatively reliable, and not on any statistical modelling. Apart from Limpopo, Mpumalanga and to some extent KwaZulu-Natal display levels of achievement which would appear much lower if only the percentage of candidates were considered. The opposite is true for Western Cape. Importantly, high percentages of the youth population do not necessarily point to a particularly effective schooling system. It may be that options outside school are so limited that more learners remain in school up to Grade 12. Nonetheless, it can be considered beneficial in many senses if a greater proportion of young people in a province reach critical mathematics thresholds at school.

[40] See https://www.thembisa.org. As the Thembisa statistics are not broken down by race, they could not be used for earlier Figure 18.

[41] Education Management Information System.

[42] Details in Gustafsson (2022). These estimates would draw from both public and independent school enrolment.

Figure 26: Proportion of all youths with 60% in mathematics in 2022, by province



Note: The numerator for all columns and for the red markers are the same within each province. It is the denominators that differ.

It is worth underlining how very different the patterns seen in Figure 26 are from the widely reported on 'pass rates', or NSCs achieved over all candidates. While Limpopo is the best or second-best performer in Figure 26, it was the *worst* performer among all provinces in terms of the pass rate in 2022. Mpumalanga, which was below the national average in terms of the pass rate in 2022, emerges as an exemplary performer in Figure 26. This underscores the limitations of the traditional pass rate, which does not take into account dropping out before Grade 12, nor achievement of levels of Grade 12 performance which would substantially improve the chances of entering a university programme.

Figure 27 uses race-specific 'EMIS analysis' population denominators to gauge the extent to which BAC youths attain a mark of 60% in mathematics. The ranking of the provinces is not that different to what was seen when youths from all population groups were analysed (Figure 26 above), though there are some exceptions. In particular, the ranking of Western Cape drops, from position 3 in Figure 26 to position 7 in Figure 27. This reflects the fact that a particularly high percentage of learners achieving 60% in mathematics are white – in Western Cape the figure is 55% for 2022, by far the highest across all provinces (second is Northern Cape, where 33% of these high-level achievers were white). However, of all provinces, Northern Cape is the worst at ensuring that black African and coloured learners achieve a level of mathematics achievement allowing for entry into a wide range of university programmes. At the other end of the spectrum, Limpopo and Mpumalanga stand out as provinces where BAC youths are particularly likely to make this achievement, though obviously even here figures should be much higher. High probabilities of excelling among black learners in these provinces have also been found in earlier research, using NSC and population data from around 2014 – see Gustafsson (2016: 15).

The red markers in Figure 27 represent 60% mathematics achievers over candidates, considering only the BAC groups. In theory, these values should always be higher than 60% achievers over a youth cohort. However, this is not true for both Limpopo and Mpumalanga. This implies there are more candidates than youths, which should normally not be the case. One explanation for this discrepancy is that in 2022 there was an abnormal concentration of candidates reaching Grade 12, due to changes in the grades 10 and 11 promotion rules during the pandemic. How inter-provincial migration explains a further part of the phenomenon is discussed in section 4.4.

Figure 27: Proportion of BAC youths with 60% in mathematics in 2022, by province

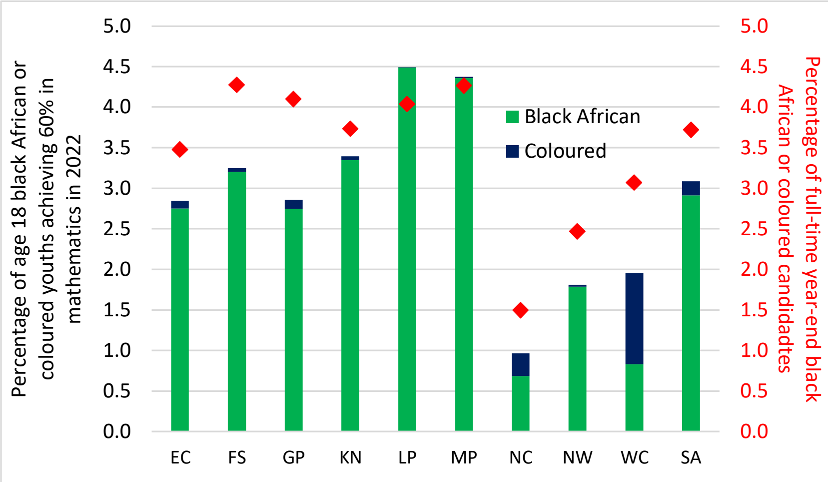


Figure 28 below provides a rough comparison to the 2017 situation. The comparison is rough insofar as only the numerator values have changed relative to Figure 27, in other words numbers of BAC achievers. It appears that the patterns seen in 2022 are patterns that have persisted for some time, with a few differences. For instances, Limpopo stood out even more as a successful ‘producer’ of mathematics skills among BAC youths in 2017. Since then, Mpumalanga has caught up to Limpopo, it appears.

Figure 28: Proportion of BAC youths with 60% in mathematics in 2017, by province

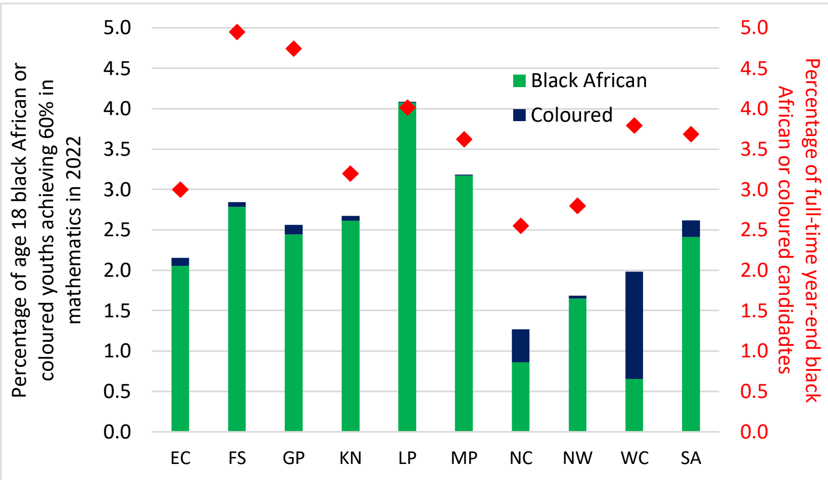


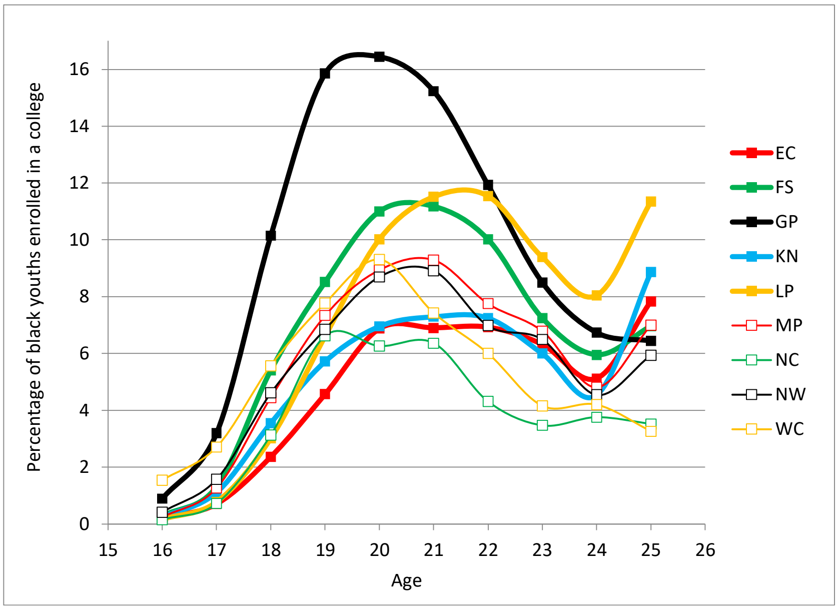
Table 5 provides figures separately for black African and coloured youths. It is noteworthy that in all provinces except for KwaZulu-Natal, coloured youths are less likely than black African youths likely to be 60% achievers in mathematics. The fact that the gap between the two population groups is larger at the national level in Table 5 relative to what was seen in Figure 18 has to do with different data sources for the denominator. For reasons given above, the EMIS-based denominator used for Table 5 (and Figure 27) appears to be the more reliable one.

Table 5: Black African and coloured breakdown 2022

	2022 black African and coloured youth denominator in Figure 27	% of these youths who are coloured	% of black African youths obtaining 60%	% of coloured youths obtaining 60%
EC	111,609	7.9	3.0	1.1
FS	43,708	3.3	3.3	1.4
GP	173,330	4.2	2.9	2.7
KN	170,897	1.0	3.4	4.8
LP	97,041	0.1	4.5	3.5
MP	64,887	0.4	4.4	3.9
NC	19,609	48.0	1.3	0.6
NW	55,410	1.5	1.8	1.5
WC	83,380	58.2	2.0	1.9
SA	822,478	9.8	3.2	1.8

A key question is whether the analysis points to, for instance, Limpopo being exemplary and Western Cape and Northern Cape being laggards when it comes to ensuring historical apartheid-like inequalities are reduced. If the 'missing' BAC youths in Western Cape in Figure 28 are achieving their skills outside the schooling system, in for instance TVET colleges, then Figure 28 can be said to be over-stating the inequalities. The next graph suggests that colleges have not historically accounted for substantial additional BAC mathematics achievers. Firstly, college students are relatively old, which would be in line with the understanding that the general trend is for youths to do Grade 12 in a school first, and then enrol in a college. Secondly, the percentage of BAC youths who are in colleges appears not to be high. For instance, age-specific BAC participation in Western Cape peaked at just 9%, at age 20, in 2016, and since 2016 college participation has not expanded much. If even a third of these youths are not captured in the Grade 12 examinations data used here, and if some 2% of these youths reach a skills level in mathematics that corresponds to the 60% mark level, then the Western Cape bar in Figure 27 would rise by just 0.06 percentage points, which would essentially not change the pattern.

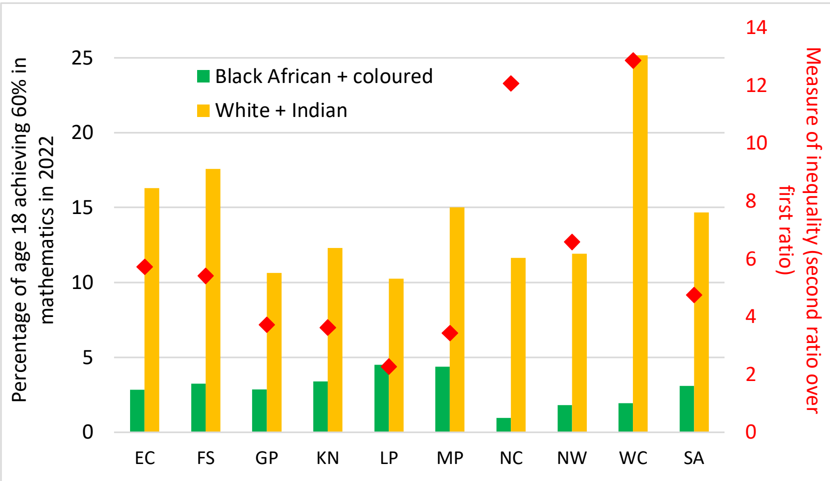
Figure 29: College participation among BAC youths by age and province (2016)



Source: Own analysis of Stats SA 2016 Community Survey microdata. Selected categories of education institution were TVET college, community education and training college and other college.

Figure 30 below compares the achievement levels of the better achieving population groups – whites and Indians – to those of black Africans and coloureds. This allows for some measure of race-based inequality to be constructed – see the red markers, which should be read against the right-hand axis. Western Cape's inequality emerges as high, both because achievement among black African and coloured youths is so low, and because achievement among white and Indian youths is so high (there are 12 times as many white candidates as Indian candidates in Western Cape, so the latter pattern is largely driven by white youths). Western Cape's, but also Gauteng's and KwaZulu-Natal's, measures of inequality is likely to rise somewhat if high mathematics achievers among the 10,000 or so candidates in the private examination systems are included. These are two provinces with especially high participation in these private systems. Limpopo's inequality is the lowest of all provinces, not just because of high achievement among BAC youths, but also because the statistic for whites plus Indians is particularly *low*.

Figure 30: Measures of race-based inequality



Note: Columns should be read against the left-hand axis, diamond-shaped pointers against the right-hand axis.

The inequalities illustrated above were examined in more depth by linking 60% mathematics achievers in 2022 at the level of the individual to learners turning 15 during 2018, using mostly the 13-digit national identity number. This can assist in detecting biases in the above analysis brought about by missing individuals in the population denominator. If there are missing learners in the denominator, the provincial achievement percentages discussed above could be higher than they should be.

The first column of statistics in Table 6 reflects 648,552 black African and coloured learners from public and independent schools across eight provinces turning 15 in 2008 for whom either a unique 13-digit ID number existed, or a unique pseudo-identifier comprising date of birth plus surname plus gender. For 93% of these learners the 13-digit ID number was available, for the remainder the pseudo-identifier was used. Western Cape is excluded as there was no race data in the 2018 data. The values in the columns headed 2019 to 2022 are numbers of full-time plus part-time mathematics 60% achievers, where candidates followed the same rule regarding unique identifiers: there had to be a unique 13-digit ID number within a year, or the birthdate plus surname plus gender pseudo identifier. Only black NSC candidates who could be found in the earlier age 15 data are included. Moreover, repeaters were removed, through counting just the first occurrence. Thus, someone who obtained 60% in 2018 and 2019 would be counted only in 2018. The final column of Table 6 is the percentage of the denominator in the first column found to achieve 60% in any of the four Grade 12 years.

Table 6: Mathematics 60% achievers over earlier age 15 for BAC

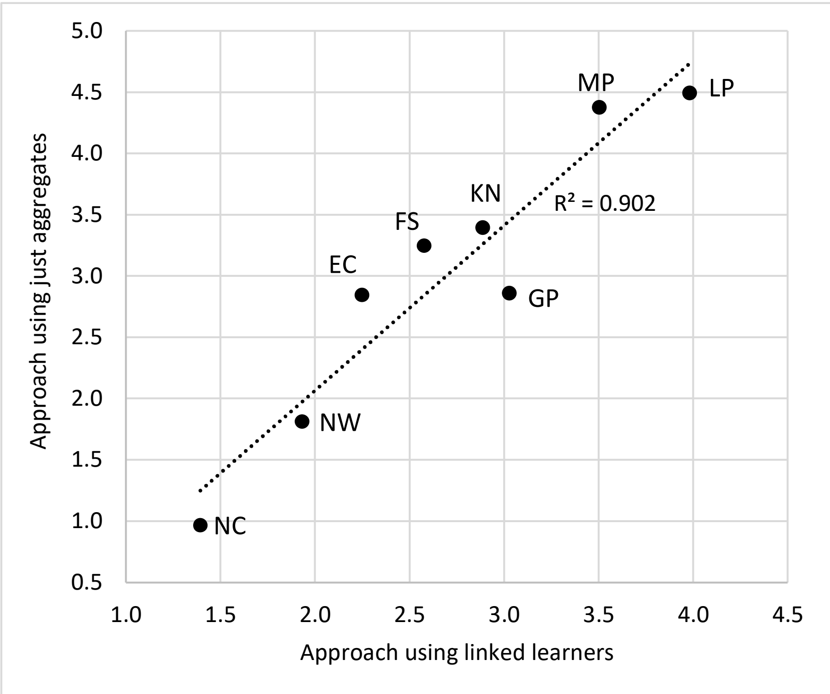
	Turning 15 in 2018	Previous over denom-inator of Figure 30	Mathematics 60% achievers among NSC					60% achievers over age 15
			2019	2020	2021	2022	Total	
EC	109,444	98	34	708	1369	293	2,427	2.2
FS	39,793	91	1	235	671	113	1,032	2.6
GP	125,949	73	15	1224	2373	223	3,928	3.0
KN	151,712	89	57	1827	1928	504	4,354	2.8
LP	94,458	97	21	1383	1928	346	3,707	3.9
MP	57,914	89	18	653	1150	283	2,119	3.6
NC	18,651	95	0	47	165	17	230	1.2
NW	50,631	91	2	287	622	55	987	1.9
8 provinces	648,552	88	148	6,364	10,206	1,834	18,784	2.9

Note: For age 15 values, province is the province in which the learner was enrolled at age 15. For the 60% achievers values, the province is the province where the learner first became a 60% achiever. Inter-provincial migration receives attention in section 4.4.

Table 6 includes part-time NSC candidates for just 2019 to 2021, years for which data for part-time candidates were readily available. Importantly, if part-time candidates are excluded, the picture barely changes. The bottom-line statistic for the eight provinces remains 2.9%, and in no province does the reduction in the statistic exceed 0.1 percentage points.

The patterns seen in Table 6 are consistent with those for BAC in Figure 30. Figure 31 below compares the two, with the horizontal axis representing the Table 6 statistics, and the vertical axis the Figure 31 statistics. Limpopo and Mpumalanga emerge as effective producers of high-level mathematics skills among black learners, while Northern Cape and North West fare poorly. Gauteng fares worse than one may expect, though using the matched learners approach this province is ranked third.

Figure 31: Different approaches to gauging provincial BAC success rates

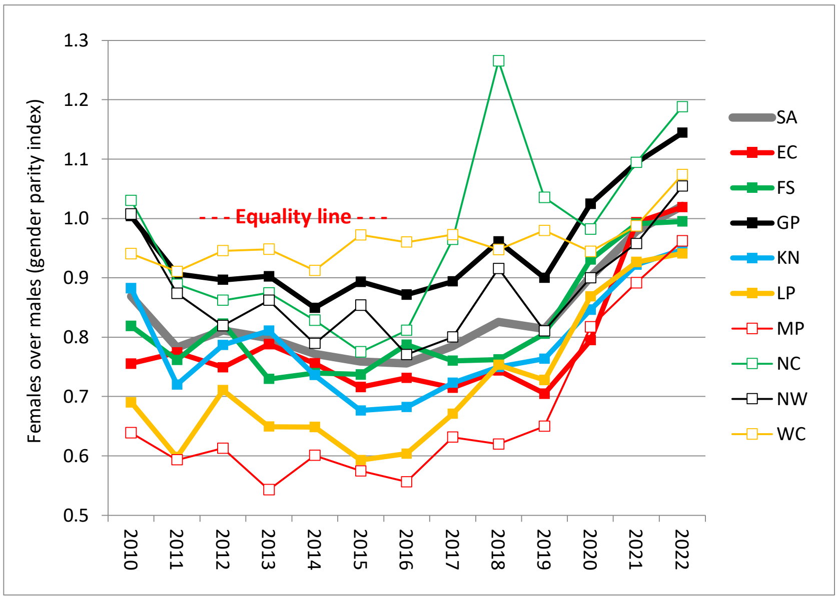


The issues raised here should be examined further, but it appears that certain provinces under-perform in the sense that they could and should be producing more high-level achievers, particularly among black African and coloured youths. Figure 27 immediately raises the question of why provinces other than Limpopo and Mpumalanga perform so far below these two. Moreover, Western Cape, but even Gauteng, with their relatively low levels of poverty, could be expected to display levels of achievement among the black African and coloured population *exceeding* that of, say, Limpopo. In 2015, Western Cape and Gauteng were the only provinces where less than 40% of the population was poor. In Limpopo, over 70% of the population was poor[43].

To provide a sense of the magnitudes, if in 2022 all provinces ensured that 4.5% of black African and coloured youths reached a level of mathematics competency represented by 60% in the NSC mathematics examination, this would increase the number of 60% achievers by 11,462, or 34% relative to the 33,874 national grand total of 2022 (this latter value is reflected in Figure 3 above).

Turning to gender inequality, South Africa displays the typical middle income country pattern of females out-performing males against several education indicators. However, mathematics is one area where males have out-performed females, at least until recently. Despite the fact that for many years more females than males obtain the NSC, more males than females have reached 40% in mathematics. However, from 2020 that clear male advantage began disappearing and in 2022, for the first time, there were as many female as male 60% achievers. These trends can be seen in Figure 32 below.

Figure 32: Gender parity index (GPI) of attainment of 60% in mathematics



4.3 Provincial Grade 12 mathematics compared to Grade 9 TIMSS

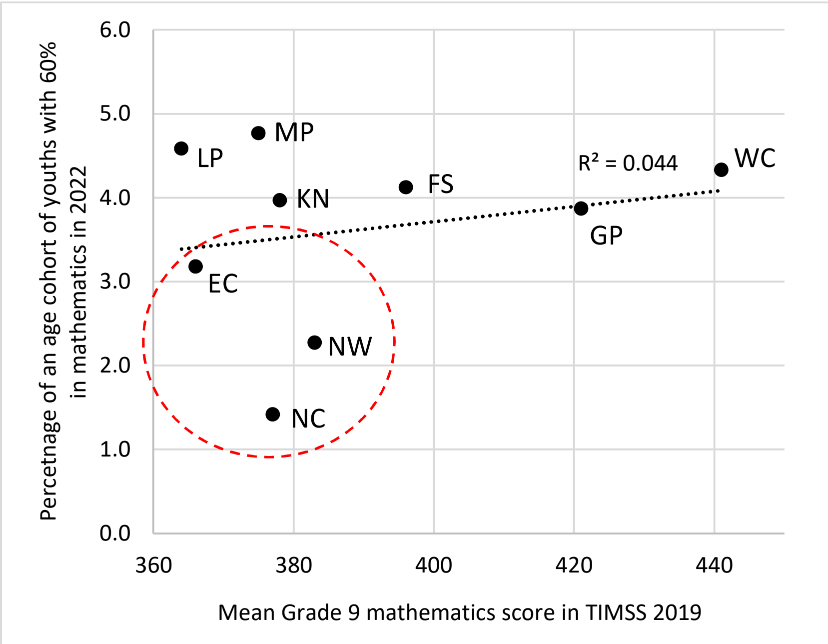
The correlation between the provincial percentages of NSC *candidates*[44] who obtain 60% in mathematics in recent years and provincial TIMSS Grade 9 mathematics mean scores of 2019 are very high. For instance, the correlation coefficient in 2022 for the nine provincial observations is 0.973. However, the correlation, again at the province level, between TIMSS Grade 9 means and the percentage of *youths* who obtain 60% in mathematics is low. Here the correlation coefficient is just 0.211. The picture is provided by Figure 33 below. There are a number of possible reasons for the low correlation, though it is difficult to draw firm conclusions without substantial further analysis. Importantly, a relatively large percentage of

[43] Statistics South Africa, 2017: 64.
[44] The reference here is to all examination candidates, not just those taking mathematics.

young South Africans, around 10%, do not complete Grade 9, and may therefore not be assessed in TIMSS Grade 9. In 2016, the difference between the best province, Gauteng, and the worst provinces, such as Eastern Cape, was twelve percentage points – around 95% of Gauteng learners successfully completed Grade 9, against 83% in Eastern Cape. This can be seen in Figure 34.

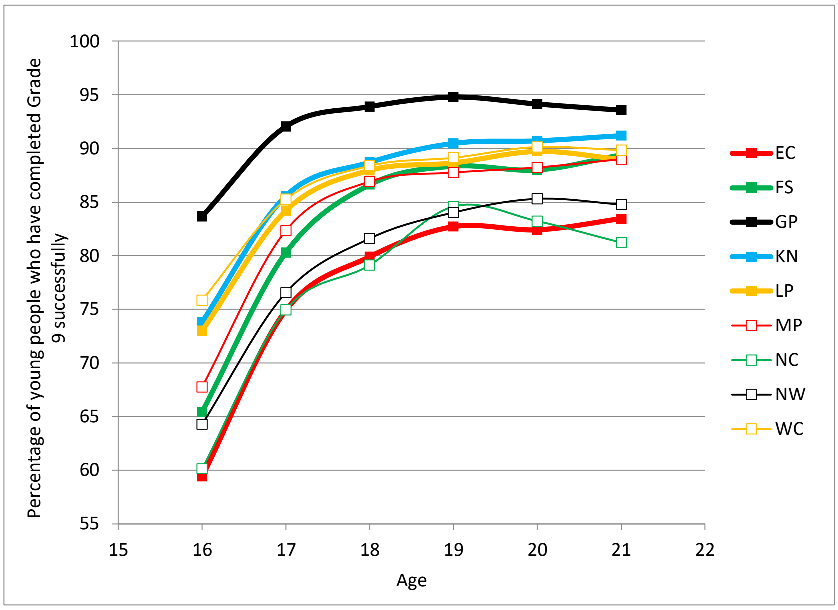
It is noteworthy that three provinces with historically low completion of Grade 9 – Eastern Cape, Northern Cape and North West – do relatively poorly when it comes to ensuring that youths reach 60% in mathematics. This is not surprising. Outside of these three provinces (in the red circle of Figure 33), the statistic on the vertical axis of Figure 33 for the six provinces ranges between 3.9% (Gauteng) and 4.8% (Mpumalanga). The surprising pattern is arguably that there is not a stronger correlation between Grade 9 and Grade 12 performance among these six provinces. In particular, why are the Grade 12 statistics so favourable in Limpopo and Mpumalanga, given the very low Grade 9 point of departure? And why are the Grade 12 statistics not *more* favourable in Western Cape and Gauteng, given their relatively *good* point of departure in Grade 9? These questions guide the analysis of section 4.4 below.

Figure 33: Grade 12 in 2022 compared to Grade 9 in 2019



Sources: Values along the horizontal axis are from Reddy et al (2022). Values along the vertical axis are those of the yellow bars in earlier Figure 26.

Figure 34: Youth who successfully completed Grade 9 in 2016



Source: Own analysis of Stats SA 2016 Community Survey microdata.

4.4 Across-school inequalities

Table 7 provides some context to the subsequent analysis of across-school distributions of mathematics results. The table reflects the 2021 data[45], but similar patterns are found in earlier years. There were 7,407 examination centres, which in the great majority of cases are secondary schools. Of these, 8% were independent. For this analysis, public and independent centres were in each case divided into two groups: those with just black African and coloured learners, and those with a wider demographic mix, meaning there had to be at least one Indian or white candidate[46]. Given the large race-based inequalities discussed in section 3, it can be assumed that a wider demographic mix is very likely to reflect more privileged schools, often schools in suburbs, while schools with exclusively black African and coloured learners are more likely to be township and rural schools. Indeed, public schools considered 'more mixed' in the table are more likely to have to candidates achieving 60% in mathematics: 8% of candidates in these public schools achieve 60% in mathematics, against a 3% figure for the 'just BAC' category. If only BAC candidates are considered, then the probabilities are 2.9% for 'just BAC' public schools and 4.5% for 'more mixed' public schools[47]. Black African and coloured youths in the more mixed schools are thus more likely to reach higher levels of mathematics achievement, even though the difference is not that great. Of note is the fact that despite these differences, the great majority of high-level achievers among black African and coloured learners come from schools which are 'just BAC' – 17,551 from such public schools against 5,966 from 'more mixed' public schools. This reflects the fact that there are far more 'just BAC' schools than 'more mixed' schools. Schools classified as neither public nor independent in the data are nearly all Limpopo centres intended for repeaters. The total number of independent school candidates, around 26,000, is well over half of the around 38,000 Grade 12 learners in independent schools in recent years reported in the official enrolment reports of the DBE. Thus, over two-thirds of independent school learners write the public examinations, and as opposed to private examinations. Moreover, there are more independent school candidates in 'just BAC' schools

[45] This year was selected as the data included part-time candidates.
[46] There are a few public schools with no black African or coloured learners, but this is very rare. Of 1,092 'more mixed' public centres in Table 7, six were such schools, and these had a full-time enrolment of 109 white or Indian candidates altogether. This did not seem to justify creating a separate category of schools in the table.
[47] Here only full-time candidates are considered.

than in ‘more mixed’ independent schools. Finally, independent school learners are more likely to achieve 60% in mathematics than their public school counterparts: 11% do so in ‘more mixed’ independent schools, and 8% in ‘just BAC’ schools. The better outcomes in independent schools are very likely to be a reflection of home background advantage, but could also be linked to greater school effectiveness, though the evidence in this regard is limited.

Table 7: Centres and candidates in the 2021 NSC data

		NSC candidates				Achievers of 60% or more in mathematics		
	Centres	Full-time	Part-time	Any time BAC	Any time white/ Indian	Full-time BAC	Full-time white/ Indian	Part-time
Public - just BAC	5,471	548,449	55,455	603,904		17,551		395
Public - more mixed	1,092	145,090	26,688	134,009	37,769	5,966	8,016	365
Sector blank	272	226	22,802	22,987	41	4	0	162
Indep. - just BAC	336	15,874	5,340	21,214		1,282		110
Indep. - more mixed	236	9,639	8,907	15,523	3,023	612	1,020	442
Total	7,407	719,278	119,192	797,637	40,833	25,415	9,036	1,474

Table 8 below provides details per province, but excluding the ‘Sector blank’ group from the previous table. Across all provinces except Gauteng, at least 96% of black African and coloured full-time candidates are from public schools – Gauteng’s figure is a lower 92%. In all provinces except Gauteng and Western Cape, over 70% of black African and coloured full-time learners are from schools which encompass only this demographic group. Among black African and coloured candidates obtaining 60% or more in mathematics, 93% are from public schools and 69% from public ‘just BAC’ schools. Clearly, the not uncommon notion that a substantial majority of black high-level achievers in mathematics are from suburban schools is not supported by the evidence for the country as a whole, though the statistics suggest this could be the case in Western Cape, where 71% of BAC high-level achievers are from the ‘more mixed’ set of schools (100% minus 29% in the table is 71%).

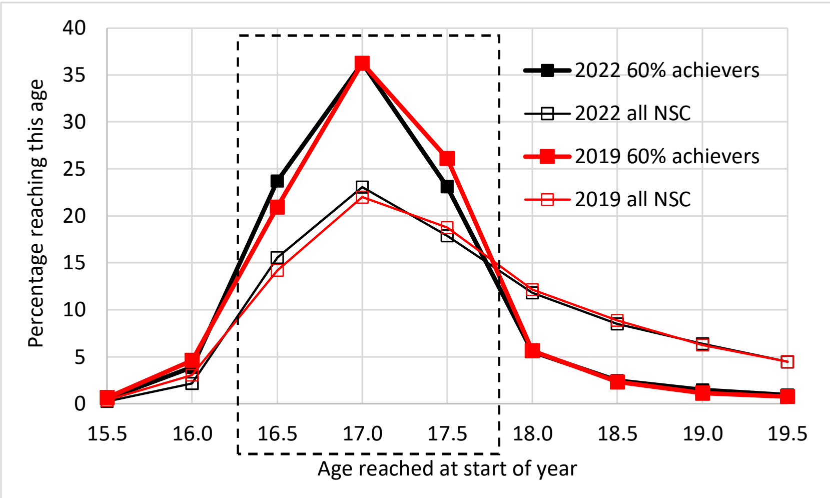
Table 8: Candidates and achievers in the 2021 NSC data

	All full-time black African and coloured candidates		Full-time black African and coloured reaching 60% in mathematics					
	% in public 'just BAC'	% in public	Public - just BAC	Public - more mixed	Indep- endent	% in public 'just BAC'	% in public	Part-time BAC with 60% in math.
EC	89	96	2,542	547	234	76	93	115
FS	80	98	894	336	45	70	96	77
GP	61	92	2,293	1,795	689	48	86	530
KN	87	99	4,217	1,089	133	78	98	168
LP	92	97	3,711	511	408	80	91	166
MP	86	96	2,340	416	123	81	96	78
NC	72	98	144	109	8	55	97	4
NW	90	98	941	226	43	78	96	73
WC	57	97	469	937	211	29	87	144
SA	81	97	17,551	5,966	1,894	69	93	1,355

The following four graphs examine age distributions. It is perhaps to be expected that grade repetition patterns will result in high-level achievers obtaining the NSC at a lower age than other candidates, and that more socio-economically disadvantaged groups will take longer to become high-level achievers. As will be seen, these assumptions do not always hold true.

Figure 35 below indicates high-level mathematics achievers are indeed on average younger than NSC achievers in general. The dotted rectangle includes ages that would be expected if there was no grade repetition and entry into Grade 1 followed the rules perfectly. The rules specify that a child should be at least 5.5 years at the start of the calendar year when Grade 1 occurs, but also not 7.0 years or older. This translates to a range of 16.5 to 17.5 in Grade 12. It is noteworthy that some 5.0% of high-level achievers in 2022 were officially *under*-aged. That this should appear is not surprising given that in past years around one-sixth of children have entered Grade 1 before the point at which policy specifies they should enter[48]. What Figure 35 also shows is that age patterns did not change much between 2019 and 2022, despite the pandemic.

Figure 35: 2019 and 2022 ages across all population groups



Note: For this graph and the following three, only full-time examination candidates were considered.

Figure 36 below reveals that the under-aged 60% achievers in 2022 were mostly black African. White candidates appear to follow a different pattern to those of the other three groups, making white high-level achievers older than other high-level achievers. The average ages of 60% mathematics achievers in 2022 are 17.3 for Indian achievers, 17.4 for black African and coloured achievers (this was calculated separately for the two groups) and 17.5 for white achievers. The pattern for NSC achievers in general is very different: here black African and coloured candidates display the highest ages[49]. Figure 37 confirms what could be expected, namely that across all population groups younger NSC achievers have a higher probability of being 60% mathematics achievers. It is possible that under-aged black African achievers, of whom there were 1,517 in 2022, were allowed to enter Grade 1 early because they displayed exceptionally good academic skills. As seen above, this phenomenon is only really visible among black African learners.

[48] Gustafsson, 2010: 7.

[49] The mean ages at the start of the year for all NSC in 2022 were 17.3 for Indian, 17.6 for white, 17.7 for coloured and 18.2 for black African.

Figure 36: 2022 ages of 60% mathematics achievers by race

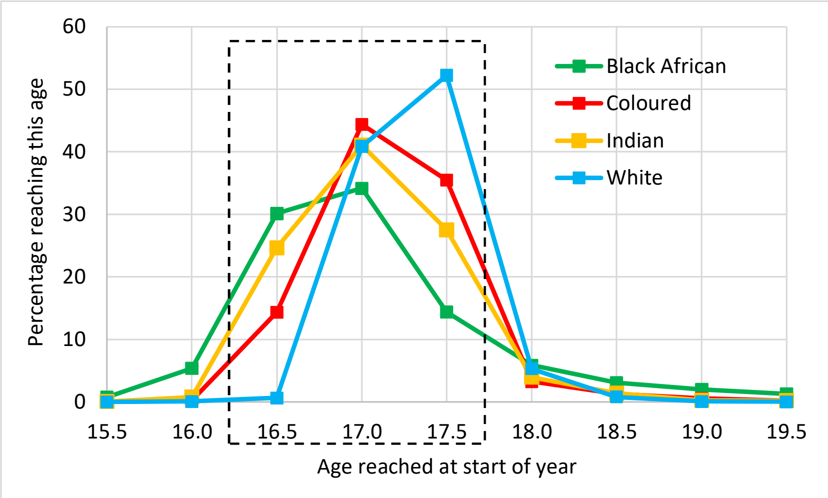


Figure 37: 2022 rates of success by age and race

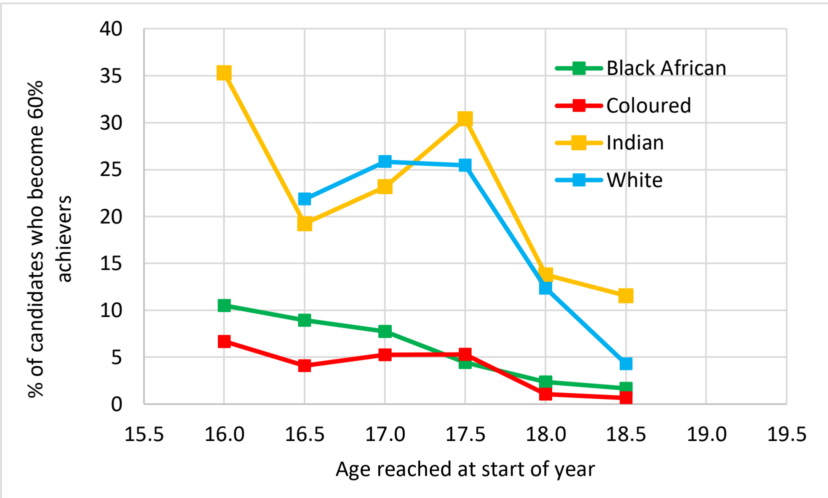


Figure 38 examines age distributions, for black African and coloured high-level achievers, by province. Under-aged 60% achievers are especially prominent in Eastern Cape. Western Cape's curve lies clearly to the right of the curves of other provinces. However, Western Cape also has a low presence of high-level achievers in the *over*-aged part of the graph. This explains why Western Cape's average age for black African and coloured high-level achievers is no different from the national average – see Table 9.

Figure 38: 2022 ages of BAC 60% mathematics achievers by province

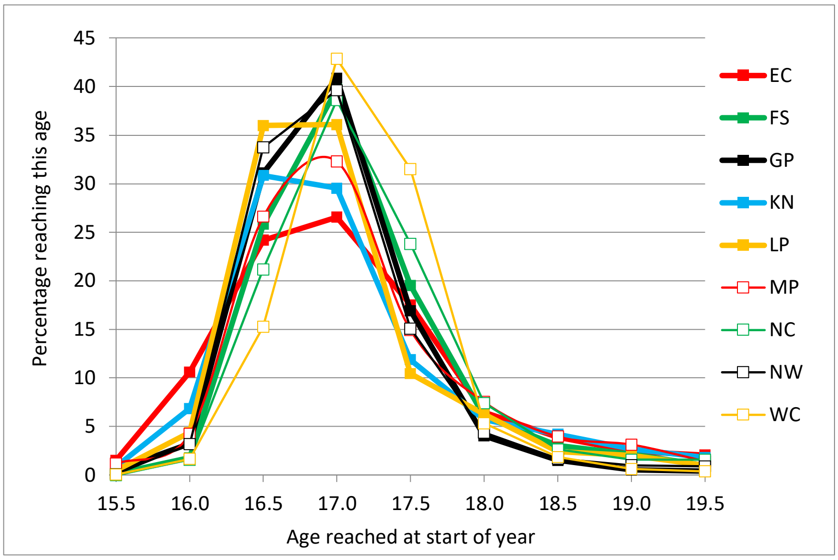
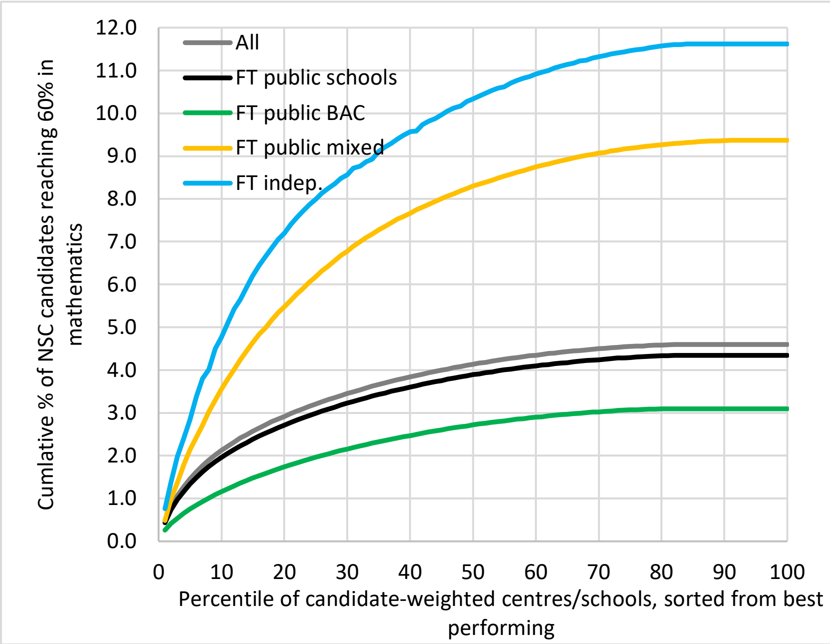


Table 9: 2022 average of of black African and coloured 60% achievers

Province	Average age start of year
EC	17.5
FS	17.3
GP	17.2
KN	17.5
LP	17.2
MP	17.5
NC	17.4
NW	17.2
WC	17.4
SA	17.4

Figure 39 below illustrates national distributions through cumulative percentile plots, where the first percentile reflects the best one-hundredth of schools in terms of the percentage of candidates who achieve 60%, and so on. To illustrate, 3.1% of black African and coloured candidates in public 'just BAC' schools achieve the 60% threshold in. Half this is accounted for by the best 15% of schools – see the green curve at 1.5 on the vertical and 15% on the horizontal. The horizontal right-hand end of the green curve covers 21 percentiles, illustrating the fact that 21% of schools make no difference to the overall statistic as they have zero high-achieving mathematics candidates. Note that each percentile represents an equal number of learners, who are grouped by schools, not an equal number of schools. This is what the use of candidate-weighted centres means.

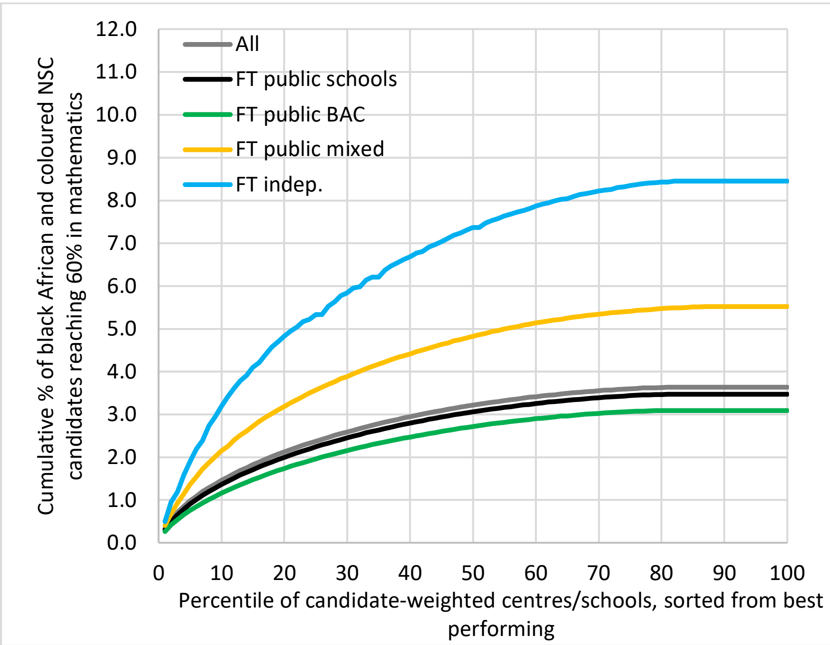
Figure 39: 2022 distribution of 60% achievers over candidates



Note: Only the 'All' curve includes part-time candidates.

Figure 40 reproduces the same graph, but counting just black African and coloured learners. The green curve is the only curve that does not change, as by definition the 'public BAC' category of schools has only black African and coloured candidates in both the previous and the next graph. The black curve in Figure 40 points to the fact that 16% of public schools produce half of all black African and coloured 60% mathematics achievers.

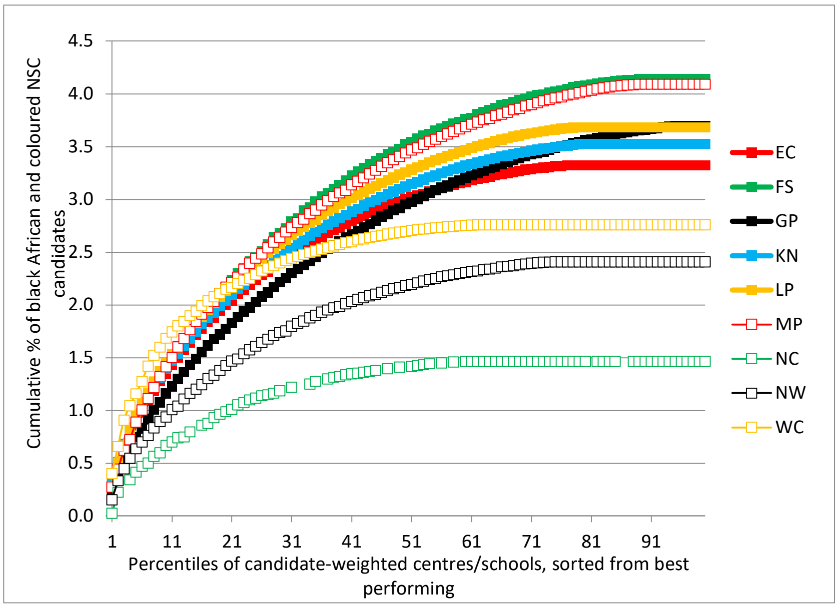
Figure 40: 2022 distribution of 60% achievers over candidates – just BAC



Note: By definition the green 'FT public BAC' would be the same in this graph as the previous graph.

Figure 41 provides the provincial versions of the black 'FT public schools' curve from Figure 40[50]. Apart from the problem of relatively low levels of mathematics success among black African and coloured candidates in three provinces – Northern Cape, North West and Western Cape – a further problem of high inequality *within* this demographic group in Western Cape is visible. The steepness of the left-hand end of the Western Cape curve points to a high reliance on relatively few schools in producing black African and coloured achievers. This will be examined further.

Figure 41: 2022 distribution of BAC 60% achievers over BAC candidates, by province



Note: While the graph focusses on black African and coloured learners, its focus is such learners across all types of public school, including the 'more mixed' schools. There are 6,332 schools underpinning this graph.

Media attention given to exceptionally well-performing schools can create the impression that a very small handful of schools are alone in producing high-level mathematics skills. Figure 41 serves to warn against an exaggerated view of this. While the production of high-level skills is not evenly spread across schools – if this were the case the curves in the graph would all be straight lines – it is more than a handful of schools which account for each province's success. For instance, in Limpopo the well-known Mbilwi Secondary produced as many as 125 60% achievers in 2022, yet this 125 is a small fraction of the 3,388 60% achievers in the province as a whole. Of the 6,332 schools used to generate Figure 41, only 13 schools produced 50 or more black African or coloured 60% achievers, one being Mbilwi. Apart from Mbilwi, the other 12 were schools with only black African and coloured learners – Mbilwi has a few Indian learners. And the 13, including Mbilwi, were from just three provinces: Limpopo, KwaZulu-Natal and Eastern Cape (these three provinces account for 5, 5 and 3 of the 13 respectively). These are not provinces usually associated with academic excellence in the public discourse, so once again the findings from the data are interesting and perhaps unexpected. Mbilwi's 125 high-level BAC achievers is the second-highest figure, after a figure of 160 for Isolemamba High in the Umlazi education district in KwaZulu-Natal. After Mbilwi, the 'more mixed' school displaying the highest output of black African and coloured 60% achievers is only in position 18, and is Sunward Park High in the Ekurhuleni South District of Gauteng. This school had 45 high-level black African or coloured achievers in 2022.

[50] The 109 schools without black African or coloured candidates discussed in footnote 46 are not included in this analysis, and the remainder of graphs and tables in this section.

Figure 42 illustrates the national distribution of high-level BAC achievement from a different angle. Here the aim is to see whether schools are consistent over time. Results from 2022 examinations are compared to the pre-pandemic ones of 2019. Mbilwi is the green marker towards the top right, and Isolemamba the red marker on the top left. Isolemamba was a relatively successful school already in 2019, but improved markedly by 2022.

Figure 42: BAC 60% mathematics achievers in 2019 and 2022

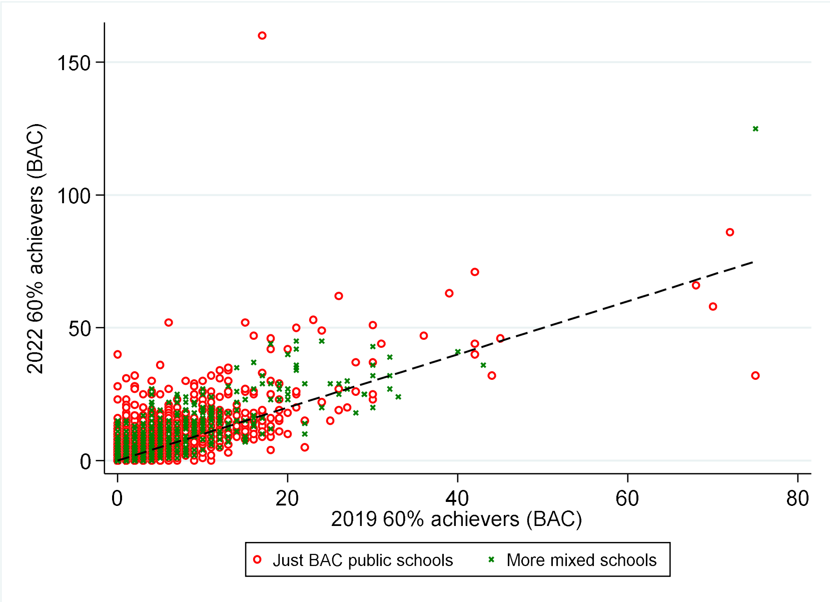


Table 10 below uses the assumption that provincial departments should pay special attention to two things. On the one hand, they should nurture schools whose output of black African and coloured 60% achievers is high, and learn from these schools so that others can emulate this achievement. On the other hand, provinces should be concerned about schools producing no 60% achievers at all. Table 10 covers all types of public schools, both the ‘BAC only’ and ‘more mixed’ categories.

With regard to the first concern, Limpopo and Eastern Cape have relatively many high-achieving schools, and these schools are mostly persistently good in Limpopo in the sense that 2.1% of Limpopo’s candidate-weighted schools produced 30 or more 60% BAC achievers in *both* 2019 and 2022. Eastern Cape came second with a figure of 1.6%. In four provinces the figure was essentially zero. Gauteng should perform better. The fact that only 1.0% of schools produced 30 or more high-level black African or coloured achievers in 2022 puts Gauteng below the national average, and in only seventh position among provinces, yet it should be relatively easy for this province to perform well against this indicator, in part because its schools are on average the largest in the country, in terms of Grade 12 candidates – see the second column of statistics. It is obviously easier to come up with 30 high-level achievers per school if schools are large. In Western Cape, eight of the nine high-achieving schools are of the ‘more mixed’ category, while in Gauteng this is true for three of the five. The figures for Eastern Cape, KwaZulu-Natal and Limpopo are 2, 3 and 4 ‘more mixed’ schools respectively, meaning in these provinces most high-achieving schools are of the ‘BAC only’ category. Of the 62 high-achieving schools reported on in Table 10, 42 are in the ‘just BAC’ category.

Turning to schools with no black African or coloured 60% achievers, Western Cape stands out for its high 2022 value of 38% – see the right-hand panel of Table 10. This, in combination with its relatively high values for high-performing schools, suggests an over-reliance on a few schools, and an insufficient spreading out of achievement across the provincial system. Northern Cape is in an even worse situation, with no schools displaying 30 or more high-achievers, and the country’s worst value with respect to zero achievers. Western Cape and

Northern Cape also emerge in an unfavourable light if schools with no 60% black African or coloured achievers in *either* 2022 or 2019 are considered – see the last column of the table.

Table 10: Elite and unsuccessful public schools 2019 and 2022

	Correl-ation of number of 60% achievers across 2019 and 2022	Mean candid-ates (counting only BAC learners)	Schools with 30 or more BAC achieving 60% in 2022	These schools as % of all schools (weighted)	% schools with 30 or more BAC achieving 60% in both 2019 and 2022	Schools with no BAC achieving 60% in 2022	These schools as % of all schools (weighted)	Schools with zero BAC achieving 60% in both 2019 and 2022
EC	.69	101	12	3.7	1.6	372	23	18
FS	.58	103	3	1.5	0.0	79	11	7
GP	.72	168	5	1.0	0.2	90	5	2
KN	.62	94	16	2.1	1.0	660	20	14
LP	.87	83	13	3.6	2.1	491	22	15
MP	.63	125	4	1.8	0.0	100	11	6
NC	.71	90	0	0.0	0.0	76	41	28
NW	.66	97	0	0.0	0.0	165	26	17
WC	.84	136	9	2.4	1.5	173	38	26
SA	.72	106	62	2.2	0.9	2,206	19	13

Figure 43 below illustrates the location of the 62 schools referred to in the above table, with markers being larger for the 22 which had at least 30 high-achieving black learners in *both* 2019 and 2022.

Figure 43: Location of schools with 30 or more BAC 60% achievers

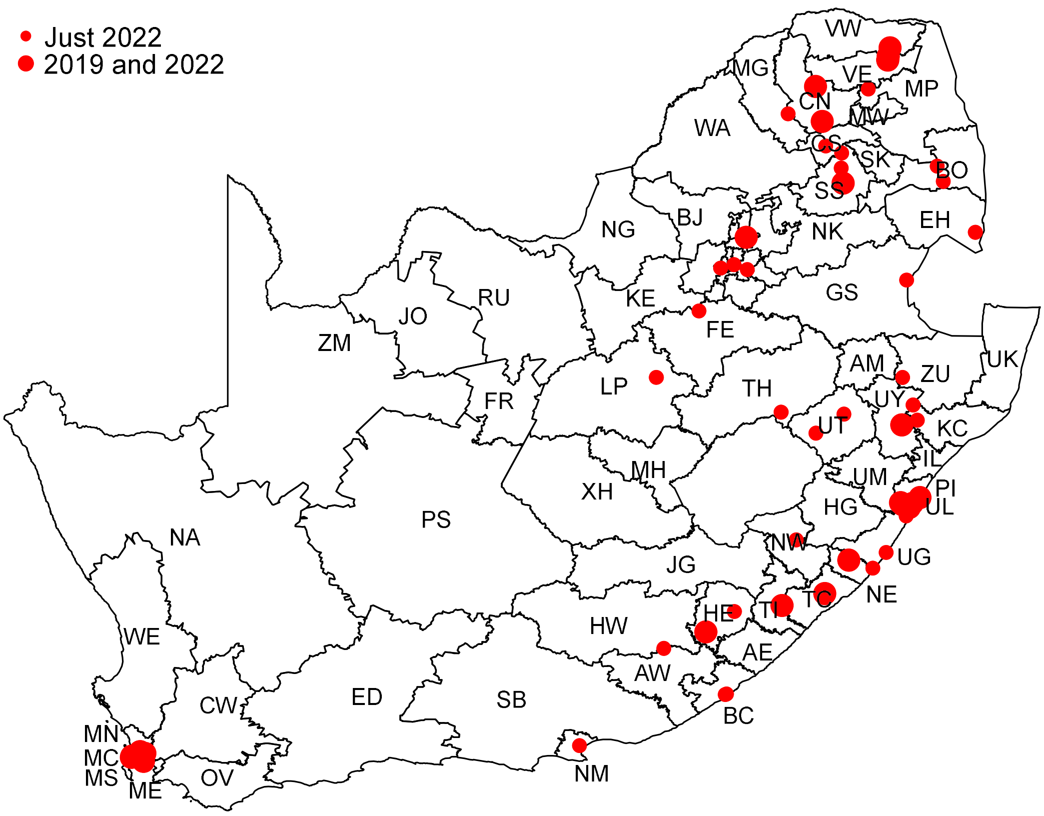


Table 11 below provides further details on the backgrounds of the linked 20,185 60% achievers among black African and coloured candidates in the years 2019 to 2022 – the linking method is the same as that used for earlier Table 6. Here Western Cape is included as the absence of race data for the earlier age 15 group does not matter as the objective is not to calculate the probability of achievement. Here the objective is to look only at the 20,185 learners and their backgrounds in terms of, in particular, province and school[51]. The second to sixth columns of Table 11 all contain percentages of the learners shown in the first column. The province with the highest percentage of high-level mathematics achievers who are 'imports' from other provinces is Western Cape, where 158 of the 1,379 high-level BAC achievers, or 11%, are from other provinces, the starting point for the analysis being age 15. Table 12 provides details on where the in-migration comes from: 3.3% of high-level BAC achievers in Western Cape were from Eastern Cape, the largest sending province. The second-largest was Northern Cape, and so on. Table 12 also reveals the *net* migration into the pool of a province's high-level achievers. It can be seen that although Mpumalanga has the highest in-migration statistics in Table 11, of 7%, its *net* in-migration is lower, as represented by the 3.7% in the bottom row of Table 12. Notably, the net in-migration for Gauteng is not high, at 2.0% of all high-level achievers.

Of the 20,185 learners analysed in Table 11, 98% had EMIS school identifiers in both the age 15 and the NSC data, after a few EMIS school identifiers in the NSC data which could not be found in the EMIS system were made blank. The lowest degree of linking was in Gauteng, where 95% of high-level BAC achievers had valid school identifiers across both datasets. The school identifier situation was thus relatively good, allowing for a sufficiently accurate analysis of movements across schools. As seen in Table 11, a change in school between age 15 and 60% mathematics achievement in Grade 12 applies to 20% of the individuals concerned, with this being most common in Eastern Cape, a province that is unusual for having a high number of schools with Grade 9 as the highest grade. But even in Eastern Cape, 83% of the high-level achievers were in a school which offered Grade 12, when they were aged 15. Yet many learners switched schools even if they did not have to: nationally, 14% of the 20,185 learners moved to another school, even if the original school offered Grade 12. The last two columns of Table 11 indicate what percentage of the learners considered in column 'A', meaning learners switching school without a need to do so, moved to a better or worse performing school. The performance of a school was gauged using 60% achievers in mathematics over *all* candidates, not just mathematics candidates, and for this calculation the data from all population groups were used. Across all provinces, over half of the concerned learners moved to better schools, while nationally 38% moved to schools which performed worse on the indicator. The patterns suggest that learners are more often than not successful in gauging where to locate better quality in the system.

[51] For Western Cape, race as specified in the NSC data is used while for other provinces the race as specified in the age 15 enrolment data is used (as was the case in earlier Table 6). The sum in the first column of Table 11 across the first eight provinces is 18,806. This differs slightly from the 18,784 seen in Table 6. The reason for this is that Table 11 totals include, for instance, a few learners who moved from Western Cape to Eastern Cape. Such learners would have been excluded in Table 6 due to the lack of Western Cape race data for the 2018 age 15 learners.

Table 11: Details on linked black African and coloured learners

	60% achiev-ers	% from other prov.	% school change*	% 2018 school had Grade 12*	% school change even if Grade 12 in same* (A)	% took longer to reach Grade 12	'A' moving to better school	'A' moving to worse school
EC	2,439	2	31	83	15	13	55	45
FS	1,032	3	21	87	7	7	57	43
GP	3,934	6	19	102	11	7	62	38
KN	4,356	1	17	98	14	12	60	40
LP	3,708	1	15	99	12	14	62	37
MP	2,120	7	29	88	17	15	58	42
NC	230	3	23	84	8	2	74	26
NW	987	3	12	99	9	7	64	36
WC	1,379	11	17	97	13	3	82	18
SA	20,185	4	20	95	13	11	62	38

*Note: For the school change calculations (see *), the few learners without a valid school identifier were removed from the denominator.*

Table 12: Across-province movements for BAC learners

To ➔ From 🡻	EC	FS	GP	KN	LP	MP	NC	NW	WC
EC		0.2	0.1	-0.1	-0.1	0.1	0.0	0.0	3.3
FS	-0.1		0.2	-0.1	-0.1	0.0	-0.4	-0.1	0.9
GP	-0.1	-0.7		-0.6	-0.9	0.1	-0.9	-0.3	1.3
KN	0.2	0.4	0.7		-0.1	0.8	0.0	0.4	1.0
LP	0.1	0.2	0.9	0.0		2.5	0.0	0.3	0.1
MP	-0.1	0.1	-0.1	-0.4	-1.4		0.0	-0.3	0.4
NC	0.0	0.1	0.1	0.0	0.0	0.0		0.0	2.2
NW	0.0	0.1	0.1	-0.1	-0.1	0.1	0.0		0.5
WC	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	
Net	0.5	0.4	2.0	-1.2	-2.6	3.7	-1.3	0.0	9.9

Note: Values represent net *in-migration, the denominator being all high-level BAC achievers per province (first column of the previous table). For instance, 58 learners moved from EC to WC, and 12 in the opposite direction, giving a net figure of 46, and 46 over Western Cape's 1,379 high-level achievers gives the 3.3% seen in this table.*

Perhaps the most telling pattern from Table 11 relating to the provincial rankings examined earlier is the fact that Limpopo and Mpumalanga, two provinces with remarkably good rankings, are also the provinces where black 60% achievers are most likely to have repeated, even before the first achievement of a 60% score[52]. According to the fifth column of the table, 14% and 15% of the high-achieving learners have repeated. This points to the possibility of an effective use of grade repetition to maximise the potential of the learner. More details on the exact mechanics of this are likely to be revealed through further analysis of the available data.

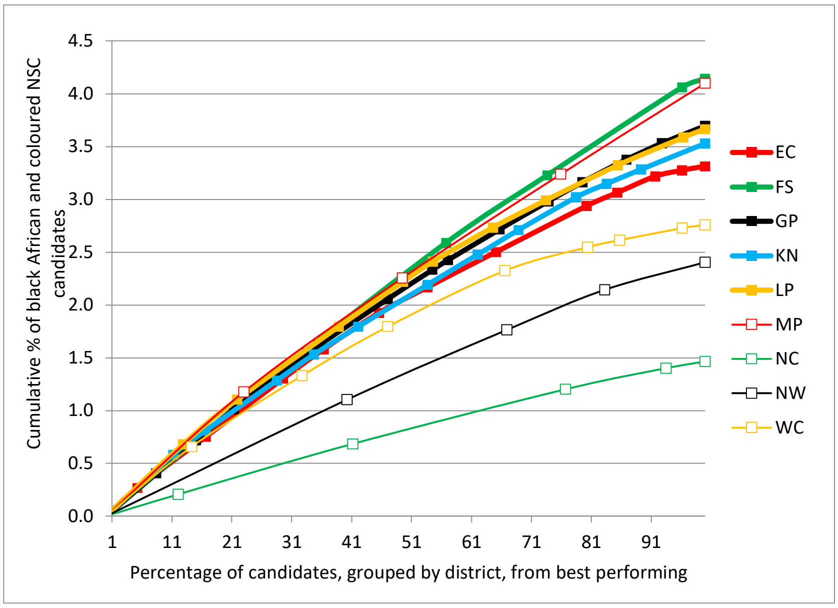
4.5 Across-district inequalities

Figure 44 below is like earlier Figure 40, except here learners are grouped by district within each province. The straighter the provincial line, the more equality there is across districts. Two provinces display a clear flattening of the slope on the right-hand side of the graph: Western

[52] The fact that Limpopo's average age in Table 9 is low should not be seen as contradicting the finding regarding grade repetition. Table 11 deals only with grade repetition for older learners, and ignores repetition that could have occurred in the earlier grades.

Cape and Eastern Cape. This points to specific districts in each province which perform rather poorly compared to other districts in the province.

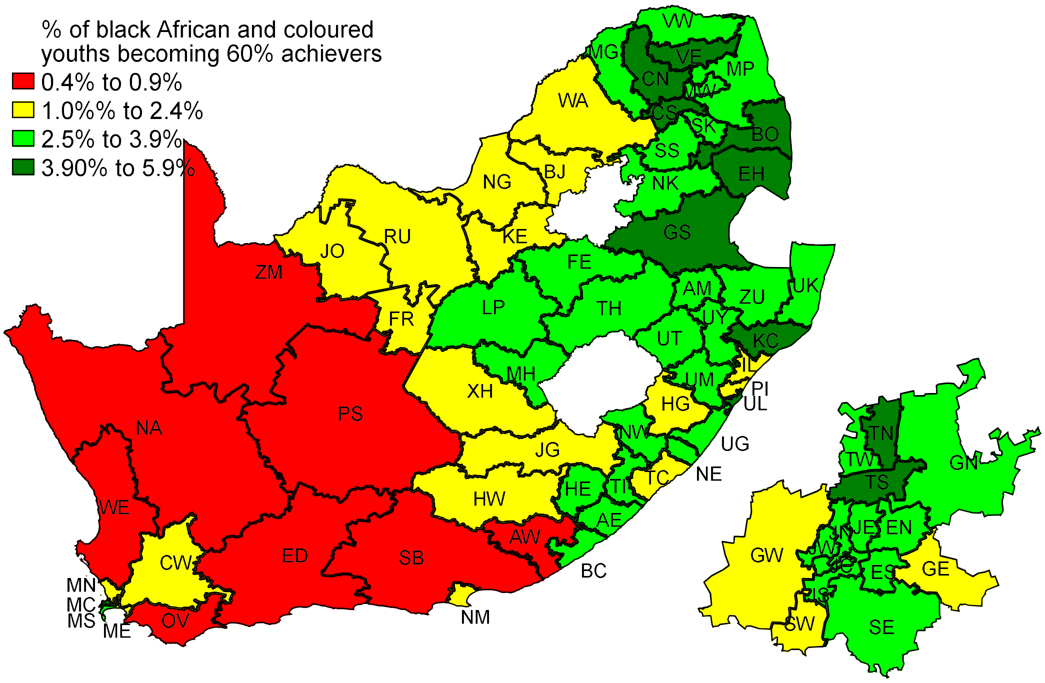
Figure 44: 2022 distribution of BAC 60% achievers over BAC candidates, by province



Note: Underlying this analysis are 6,302 public centres/schools with full-time candidates. The difference of 30 between this and the 6,332 schools of Figure 41 is accounted for by centres absent in the official master list of schools mostly due to their being adult education centres. Markers in the graph reflect districts.

The map in Figure 45 illustrates the inequalities geographically. The focus here is on black African and coloured *youths*, not candidates, as in the above graph. In Eastern Cape, districts in the western half of the province, such as Sarah Baartman (SB), perform worse than other parts of the province with respect to 60% mathematics achievers. In Western Cape, there is considerable variation across provinces, from light green (2.5% to 3.9%) in Metro South (MS – this is the only district achieving this level) to red (0.4% to 0.9%) in several districts in the Western Cape hinterland, such as Eden (ED). There is a fairly clear alignment between, on the one hand, better performing districts in Limpopo, such as Vhembe (VE), and in Mpumalanga, such as Gert Sibande (GS) and, on the other, the location of consistently well performing schools seen in Figure 43 above.

Figure 45: 2022 BAC 60% achievers over BAC youth, by district



Note: The numerator here draws from both public and independent schools/centres, but just full-time candidates. The denominator is black African and coloured public and independent school learners in 2018 who turned 14 in 2018. For the Western Cape, where breakdowns by population group in the 2018 enrolment data were not available, breakdowns by population group per district seen in 2020 for learners turning 14 in 2020 were applied to the 2018 age 14 per district enrolment totals.

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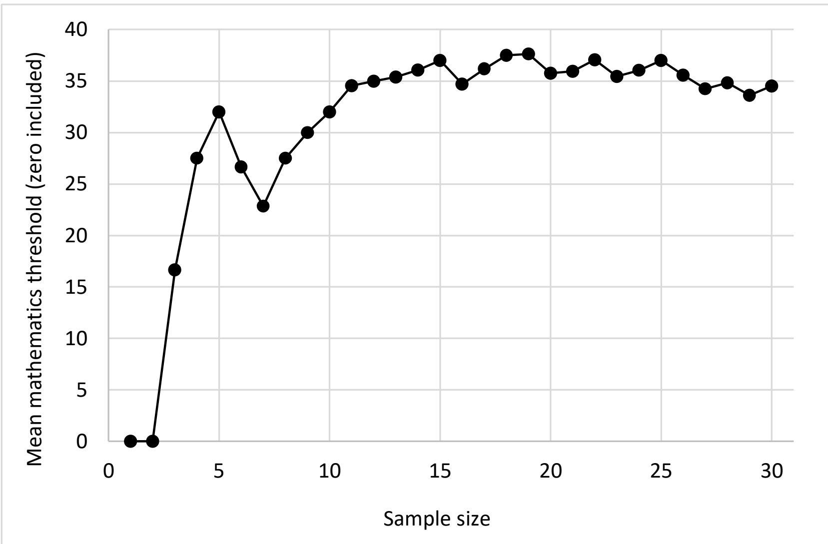
Appendix A: Using HEDA data to arrive at NSC mathematics demand

Higher Education Data Analyzer (HEDA) data were used to obtain an approximate sense of how many first-year university students should ideally have reached specific NSC thresholds in mathematics and physical sciences. The approach was to use the HEDA data querying facility and to filter headcounts by including only the following: first-time entering student; undergraduate degrees *and* undergraduate diplomas and certificates; ages 18 to 34. The focus fell on the year 2019, as the intention was to monitor patterns in a non-pandemic year. The HEDA data were accessed in March 2023. The 2019 total headcount, with the filters applied, was 162,244, of which 91,441 were in the category 'undergraduate degrees', the remainder being 'undergraduate diplomas and certificates'. The 162,244 is lower than the 187,722 first-time entrants officially reported by DHET[53], but a gap is to be expected considering the 162,244 figure covers only students up to age 34.

The HEDA extract included all 26 public universities, and 19 'CESM first order' specialisations. There were 548 combinations of university and specialisation in the extract. The ideal would have been to research online the entrance requirements with respect to mathematics, and physical sciences for all these 548 cases. However, to save time 30 cases were selected randomly, with probability proportional to size (PPS), meaning cases with more first-time students were more likely to be sampled. Figure 46 reflects the average threshold in the mathematics entrance requirement found as the sample expanded. The first two sampled cases had no requirements, and hence the mean was zero. The third case displayed a mark threshold of 50, so the mean became 17. And so on. Clearly, the mean stabilised soon after 10 cases had been sampled. This suggests that the sample of 30 provides a sufficiently representative sample for the purposes of the analysis. Obviously, the sample could be expanded in a future analysis to reach a greater level of certainty.

Figure 46: Effect of sample size on average threshold



In establishing the mathematics and physical sciences thresholds for particular cases, thresholds that would apply without a school-to-university bridging course were used, as the intention was to gauge what the demand was in an ideal situation where schools had prepared students adequately for university studies. Moreover, where a university had an alternative, and higher, threshold for an applicant with only mathematical literacy, this was ignored. In other words, it was assumed that university students studying in some programme where mathematics was considered important, would have taken mathematics in the Grade 12 examinations. Again, this

[53] Department of Higher Education and Training, 2021: 15.

can be considered an ideal. Finally, in the few instances where an area of study at a university had different mathematics thresholds, depending on sub-specialisation, the higher threshold was chosen. Details on how common this was appear in Table 14.

Table 13 below provides the final results of the analysis. They are discussed in section 2.1.

Table 13: Results of the 30-case analysis

Combinations of mathematics and physical sciences thresholds	Cases	% of cases	Extrapolated first-time undergraduates
0-0	10	33	54,081
40-0	4	13	21,633
50-0	5	17	27,041
50-50	3	10	16,224
60-0	3	10	16,224
60-40	1	3	5,408
60-50	1	3	5,408
60-60	3	10	16,224
60-X	8	27	43,265
Any math. threshold	20	67	108,163
Total	30	100	162,244

Table 14 below provides details relating to the 30 sampled cases.

Table 14: Details on the 30 cases in the sample

Sequ-ence Figure 46	Degree or diploma/ certificate	CESM first order	University	First-time entrants	Mathematics threshold	Physical sciences threshold	Some thresholds lower than this in mathematics?
24	Degree	Agriculture, Agricultural Operations And Related Sciences	UNISA	67	50	50	
11	Degree	Architecture And The Built Environment	UJ	140	60	0	
28	Degree	Architecture And The Built Environment	UP	153	50	50	
13	Dip./Cert.	Business, Economics And Management Studies	TUT	3,708	40	0	
30	Degree	Business, Economics And Management Studies	UCT	807	60	0	
9	Degree	Business, Economics And Management Studies	UJ	1,871	50	0	Yes
10	Degree	Business, Economics And Management Studies	UKZN	765	50	0	Yes
15	Degree	Business, Economics And Management Studies	UNISA	1,756	50	0	
19	Dip./Cert.	Business, Economics And Management Studies	UNISA	7,383	40	0	
12	Dip./Cert.	Business, Economics And Management Studies	Walter Sisulu	1,445	40	0	Yes
29	Degree	Communication, Journalism And Related Studies	UFS	136	0	0	
27	Degree	Communication, Journalism And Related Studies	UJ	197	0	0	
21	Degree	Computer And Information Sciences	CUT	252	40	0	
18	Dip./Cert.	Computer And Information Sciences	TUT	1,293	60	40	
17	Degree	Computer And Information Sciences	UP	434	60	0	
5	Degree	Computer And Information Sciences	UWC	287	50	0	
23	Degree	Education	CUT	589	0	0	
20	Dip./Cert.	Education	UNISA	6,771	0	0	
25	Degree	Health Professions And Related Clinical Sciences	Wits	617	60	60	
26	Degree	Languages, Linguistics And Literature	Rhodes	47	0	0	
6	Degree	Languages, Linguistics And Literature	Stellenbosch	159	0	0	
2	Degree	Law	UNISA	3,089	0	0	
16	Dip./Cert.	Law	UNISA	6,532	0	0	
8	Degree	Life Sciences	Rhodes	61	60	55	Yes
22	Degree	Mathematics And Statistics	Limpop	563	60	60	
3	Degree	Physical Sciences	Limpop	385	50	50	Yes
4	Degree	Physical Sciences	UKZN	287	60	50	Yes
14	Degree	Psychology	NMMU	227	45	0	
7	Degree	Psychology	UNISA	1,485	0	0	
1	Dip./Cert.	Visual And Performing Arts	UKZN	28	0	0	