TIMSS 2019

Highlights of South African Grade 9 Results in Mathematics and Science

Building Achievement Bridging Achievement Gaps

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Achievement and Achievement Gaps

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SECTION A: TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

Since 1995, South Africa has conducted the Trends in International Mathematics and Science Study (TIMSS) every four years (except in 2007). TIMSS is a valuable resource for South Africa to monitor its educational effectiveness. With TIMSS 2019, South Africa has an unrivalled trend data resource for mathematics and science achievement over a 25-year period.

About TIMSS

TIMSS is an assessment of the mathematics and science knowledge of fourth and eighth Grade learners around the world. A few countries, including South Africa, assess fifth and ninth Grade learners. The International Association for the Evaluation of Educational Achievement (using IEA constructed scales designed for the group of international participants, which provides South Africa with aspirational targets) designed the TIMSS assessment to allow participating nations to measure and monitor the health of their education systems, to measure achievement trends over time, and to compare their learners' educational achievement across borders (website https://www.iea.nl/studies).

The TIMSS assessments align broadly with the mathematics and science curricula of participating countries. Demographic and contextual information collected from learners, teachers, parents and schools provides a rich dataset to explain the observed achievement. Taken together, TIMSS provides comparative data about countries learner achievement and the home, school and classroom context in which they live and learn.

TIMSS in South Africa

Since 1995, the Human Sciences Research Council (HSRC) has conducted TIMSS in South Africa. The country participated at the Grade 8 level in the 1995, 1999 and 2003 cycles and at the Grade 9 level in the 2003, 2011, 2015 and 2019 cycles. TIMSS 2003 included both Grade 8 and 9 learners and provides an achievement trend measure from 1995 to 2019.

For a better insight of education and achievement in primary schools, South Africa conducted the TIMSS 2015 Numeracy assessment at the fifth Grade. TIMSS 2019 includes both the mathematics and the science assessment.

Following the TIMSS 2015 Grade 9 results, two of the higher achieving provinces, the Western Cape and Gauteng, sought a more precise provincial achievement estimate. The sample size in these two provinces, for TIMSS 2019, increased to 150 schools, while sample size in the other provinces remained at 30 schools each. The TIMSS 2019 International Results in Mathematics and Science Report, in addition to reporting information for South Africa, also reports on Western Cape and Gauteng provinces as self-standing entities called "benchmarking participants."

Why South Africa participates in TIMSS

TIMSS 1995 provided the first indicative estimate of South African mathematics and science achievement, and of the quality and outcomes of the educational system. Subsequent cycles of TIMSS provide data to monitor the trend of mathematics and science achievement and TIMSS 2019 offers the opportunity for another point to monitor, and explain, our educational achievement. The key questions informing the analysis of TIMSS 2019 data and the Highlights of Results Report are:

- What are the mathematics and science achievements and achievement gaps in TIMSS 2019?
- What are the mathematics and science trend achievements from 1995 to 2019?
- What influences mathematics and science achievement in South Africa?

Grade 9 TIMSS 2019 in South Africa

The Department of Basic Education (DBE) and the HSRC collaborated in conducting the TIMSS 2019. The TIMSS 2019 school sample was selected from the 2018 DBE List of Schools that offered Grade 9 classes (8 340 public and 736 independent). Statistics Canada selected the national sample based on province and school type (public, independent) as explicit stratification variables and school poverty ranking as the implicit stratification variable. Five hundred and twenty (520) schools[1] made up the TIMSS 2019 sample. A total of 519 schools participated and 20 829 learners, 543 mathematics and 537 science teachers, and 519 school principals completed the TIMSS instruments. We explain the TIMSS methodology in detail in the forthcoming TIMSS 2019 National Report.

Structure of the highlights of Grade 9 results report

Using the Interim TIMSS 2019 International Results in Mathematics and Science Report (Mullis, et al, 2020) published by the IEA, and with further HSRC analyses, we constructed this TIMSS 2019 Highlights of Results Report.

Section A has provided a brief outline of TIMSS to orient the reader.

Section B describes the TIMSS 2019 mathematics and science achievements. We report on achievement patterns at three levels: (i) International, (ii) National, and (iii) Local (province, fee-status of schools, and gender). We then describe the achievement trends from TIMSS 2003 to TIMSS 2019.

Section C signals possible predictors of mathematics and science achievement. From the bivariate analyses, we identified the home, school and classroom factors (through IEA constructed scales) that are associated with mathematics and science achievement.

Section D outlines the key findings emerging from this analysis.

The HSRC will publish the TIMSS 2019 National Report by June 2021. The TIMSS 2019 National Report will include more comprehensive reporting and multivariate analyses to identify robust predictors of mathematics and science achievement.

[1] This includes the 150 schools for Gauteng and Western Cape. The achievement contribution of these two provinces to the national score is scaled to an equivalence of 30 schools, in line with other provinces.

SECTION B: ACHIEVEMENTS AND ACHIEVEMENT GAPS

1. INTERNATIONAL MATHEMATICS AND SCIENCE ACHIEVEMENT IN 2019

Table 1: Mathematics Achievement

Country	Mathematics Mean (SE)
Singapore	616 (4.0)
Chinese Taipei	612 (2.7)
Korea, Rep. of	607 (2.8)
Japan	594 (2.7)
Hong Kong SAR	578 (4.1)
Russian Federation	543 (4.5)
Ireland	524 (2.6)
Lithuania	520 (2.9)
Israel	519 (4.3)
Australia	517 (3.8)
Hungary	517 (2.9)
United States	515 (4.8)
England	515 (5.3)
Finland	509 (2.6)
Norway (9)	503 (2.4)
Sweden	503 (2.5)
Cyprus	501 (1.6)
Portugal	500 (3.2)
TIMSS Scale Centrepoint	500
Italy	497 (2.7)
Turkey	496 (4.3)
Kazakhstan	488 (3.3)
France	483 (2.5)
New Zealand	482 (3.4)
Bahrain	481 (1.7)
Romania	479 (4.3)
United Arab Emirates	473 (1.9)
Georgia	461 (4.3)
Malaysia	461 (3.2)
Iran, Islamic Rep. of	446 (3.7)
Qatar	443 (4.0)
Chile	441 (2.8)
Western Cape (9)	441 (4.4)
Lebanon	429 (2.9)
Gauteng (9)	421 (3.0)
Jordan	420 (4.3)
Egypt	413 (5.2)
Oman	411 (2.8)
Kuwait	403 (5.0)
Saudi Arabia	394 (2.5)
South Africa (9)	389 (2.3)
Morocco	388 (2.3)

Thirty-nine countries and seven regional entities (called benchmarking participants) participated in the eighth-Grade assessments (Norway, South Africa, and the Western Cape and Gauteng Provinces participated at the ninth Grade). Close to half the countries administered the computerized version (e-TIMSS) and the other half administered a paper version of TIMSS. The TIMSS achievement scale is set to a Centrepoint (point of reference which remains constant from assessment to assessment) of 500 and a standard deviation of 100.

Table 1 on the left presents the average mathematics achievement (with standard errors) and Table 2 on the right the average science achievement (with standard errors) for countries who participated in the eight/ninth Grade assessments. The countries are arranged from highest to lowest achievement score.

Five East Asian countries had the highest mathematics achievement, with Singapore, Chinese Taipei and Korea performing similarly. These countries are followed by Japan and Hong Kong. The five lowest performing countries are Oman, Kuwait, Saudi Arabia, South Africa and Morocco. The achievement scores of Saudi Arabia, South Africa and Morocco are not significantly different.

Singapore had the highest science achievement, followed by Chinese Taipei and Japan who performed similarly. Korea and Russian Federation followed. The five lowest performing countries are Saudi Arabia Morocco, Egypt, Lebanon and South Africa. The achievement scores of Lebanon and South Africa are not significantly different.

Table 2: Science Achievement

Country	Science Mean (SE)
Singapore	608 (3.9)
Chinese Taipei	574 (1.9)
Japan	570 (2.1)
Korea, Rep. of	561 (2.1)
Russian Federation	543 (4.2)
Finland	543 (4.2)
Lithuania	534 (3.0)
Hungary	530 (2.6)
Australia	528 (3.2)
Ireland	523 (2.9)
United States	522 (4.7)
Sweden	521 (3.2)
Portugal	519 (2.9)
England	517 (4.8)
Turkey	515 (3.7)
Israel	513 (4.2)
Hong Kong SAR	504 (5.2)
Italy	500 (2.6)
TIMSS Scale Centrepoint	500
New Zealand	499 (3.5)
Norway (9)	495 (3.5)
France	489 (2.7)
Bahrain	486 (1.9)
Cyprus	484 (1.9)
Kazakhstan	478 (3.1)
Qatar	475 (4.4)
United Arab Emirates	473 (2.2)
Romania	470 (4.2)
Chile	462 (2.9)
Malaysia	460 (3.5)
Oman	457 (2.9)
Jordan	452 (4.7)
Iran, Islamic Rep.	449 (3.6)
Georgia	447 (3.9)
Kuwait	444 (5.7)
Western Cape (9)	439 (5.1)
Saudi Arabia	431 (2.6)
Gauteng (9)	422 (3.9)
Morocco	394 (2.7)
Egypt	389 (5.4)
Lebanon	377 (4.6)
South Africa (9)	370 (3.1)

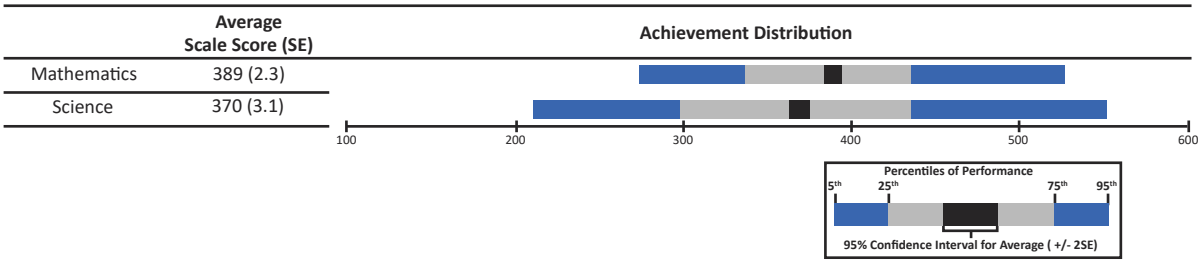
2. SOUTH AFRICAN MATHEMATICS AND SCIENCE PERFORMANCE, 2019

The TIMSS 2019 mathematics assessment comprised 211 assessment items in total, but each learner responds to only part of the assessment. In order to provide comparable scores for each learner, TIMSS uses item response theory (IRT) scaling methods to create a set of plausible achievement estimates for each learner. This is used to calculate the scale score achievement estimates. TIMSS also describes mathematics and science performance in a second way: TIMSS translates the achievement scale scores to describe the abilities learners demonstrate at particular points on the achievement scale, called international benchmarks.

2.1. South African Mathematics and Science Scale Score Achievement

The 39 participating countries (and seven benchmarking entities) include highly industrialised, middle- and low-income countries from all continents. The three countries from the African continent are South Africa, Egypt, and Morocco. South Africa is the only country from Sub-Saharan Africa. Figure 1 presents the average achievement, at the ninth Grade, for South Africa together with the scale score distribution.

Figure 1: Average mathematics and science achievement and scale score distributions, 2019



The South African average scale score for mathematics is 389 (SE 2.3) and for science is 370 (SE 3.1), with a wider achievement distribution for science than mathematics, a reflection of higher variation in learner ability.

In addition to the scale scores, Figure 1 also shows the achievement values at the 25th and 75th percentile as well as the 5th and 95th percentile. Each percentile point indicates the percentage of learners performing below and above that achievement point. The achievement distribution (the difference between achievement at the 95th and 5th percentile) for mathematics is 253 points and for science is 341 points, a difference of 88 points. Science achievements at the bottom end of the distribution are lower than the mathematics achievements, while at the top end the science scores are higher than the mathematics scores. The difference in the mathematics and science distribution suggests that science learners experience additional problems in accessing the content.

2.2. Mathematics and Science Ability by International Benchmarks, 2019

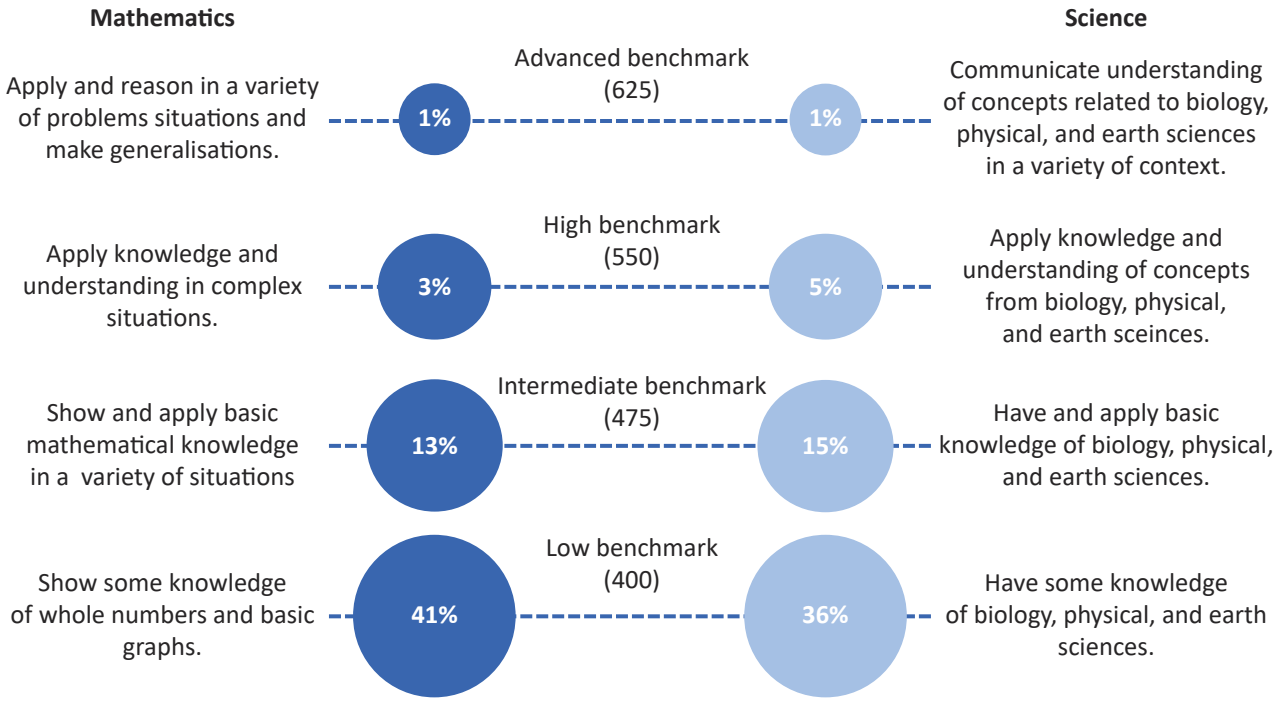
In order to interpret the TIMSS achievement scales, TIMSS describes four points on the scale called International Benchmarks in terms of mathematical and science abilities (skills or knowledge) that a learner would demonstrate. The four identified points are the Advanced International Benchmark, High International Benchmark, Intermediate International Benchmark and Low International Benchmark. Figure 2 describes the abilities that learners would demonstrate at each of these points and shows the (cumulative) percentage of South African Grade 9 learners who reached each of the levels.

On the TIMSS scale, learners who achieve above 400 TIMSS points are described as having acquired basic mathematical or science knowledge for that Grade. Higher achievements mean that learners possess abilities to apply knowledge in simple or complex situations or to generalise. It is noteworthy that 1% of learners achieved at the Advanced Benchmark and that 3% of mathematics learners and 5% of science learners scored higher than 550 TIMSS points (the High Benchmark); 13% of

mathematics learners and 15% of science learners scored higher than 475 TIMSS points (the Intermediate Benchmark).

Forty-one (41) percent of South African learners acquired basic mathematical knowledge and thirty-six (36) percent acquired basic science knowledge. This implies that 59% of learners had not acquired basic mathematical knowledge and 64% had not acquired basic science knowledge. South Africa still has a way to go to improve mathematics and science basic knowledge.

Figure 2: Percentage of learners reaching international benchmarks for mathematics and science, 2019



3. MATHEMATICS AND SCIENCE ACHIEVEMENT OF LOCAL RELEVANCE, 2019

South Africa is a big and diverse country with a population of 59 million people, categorised by population groups as 81% African, 9% Coloured, 8% White and 3% Indian. Social and economic inequalities have been persistent, primarily because of their deep roots in the country's legacy of racial exclusion under apartheid. South Africa has one of the highest levels of income inequality in the world and very high poverty levels with 49% of the population categorized as chronic poor, 13% transient poor, 14% vulnerable, 20% as middle class and 4% elite (The World Bank, 2018).

A single national achievement score does not tell the South African story. Rather, a textured achievement story reported through the categories of (i) province, (ii) poverty index of schools, (iii) fee status of schools, and (iv) gender is more revealing.

3.1. Mathematics and Science Achievement by Provinces, 2019

The National Education Policy Act of 1996 outlines the concurrent responsibilities of the National and Provincial Departments of Education for planning, provision, governance, monitoring and evaluation. The nine provincial departments of education are responsible for funding decisions and for implementing education policy and programmes in Grades R to 12. Provincial achievement estimates provide useful information to monitor the progress across the nine provincial departments.

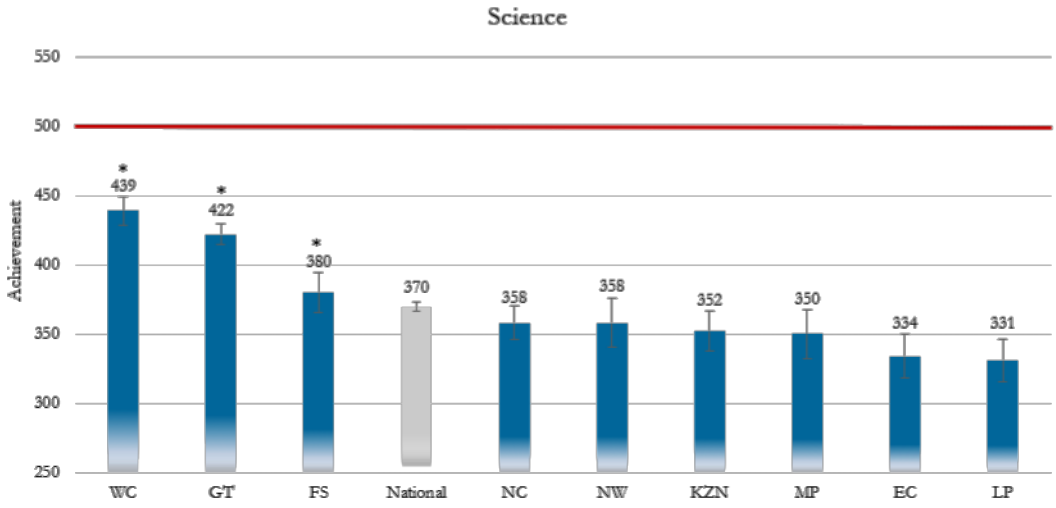
The TIMSS provincial sample sizes (except Western Cape and Gauteng) are approximately 30 schools. This smaller sample size leads to high standard errors, thus provincial achievement estimates are not as precise as national estimates. The TIMSS 2019 provincial mathematics and science achievements, with confidence intervals, are presented in Figure 3.

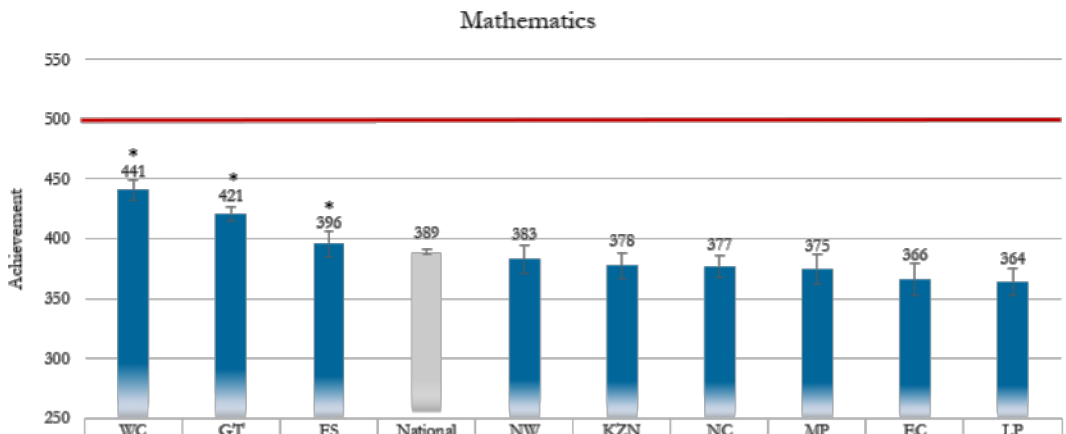
Socio-economic conditions differ from province to province. The provincial macro-indicators of economic affluence expressed through the Gross Domestic Product (GDP) and poverty rate, coupled with the size of provincial education departments and the percentage of learners in no-fee schools, paint the picture of opportunity gradient amongst provinces. These macro-level statistics are presented in the table below the provincial achievement graphs in Figure 3. Clearly, there is a relationship between the macro socio-economic indicators and the provincial mathematics and science achievements: Provinces with higher levels of economic affluence achieve higher mathematics and science achievements.

The top three performing provinces for mathematics are the Western Cape with an achievement score of 441 (4.4), Gauteng with 421 (3) and Free State with 396 (5.5) and similarly for science are the Western Cape with 439 (5.1), Gauteng with 421 (5.7) and Free State with 396 (7.4). The achievement scores of the three top provinces are significantly different from each other, as well as the other six provinces. The achievement scores for the six other provinces, Northern Cape, North West Province, KwaZulu-Natal, Mpumulanga, Eastern Cape and Limpopo, are lower than the national score and the achievements of each are not significantly different from the adjacent performing province.

None of the provinces are close to the Centrepoint score of 500 points (Red line on the diagram). The difference between the highest and lowest performing provinces is 77 TIMSS points for mathematics and 108 TIMSS points for science.

Figure 3: Provincial mathematics and science achievement, with confidence intervals, and provincial macro-level statistics, 2019





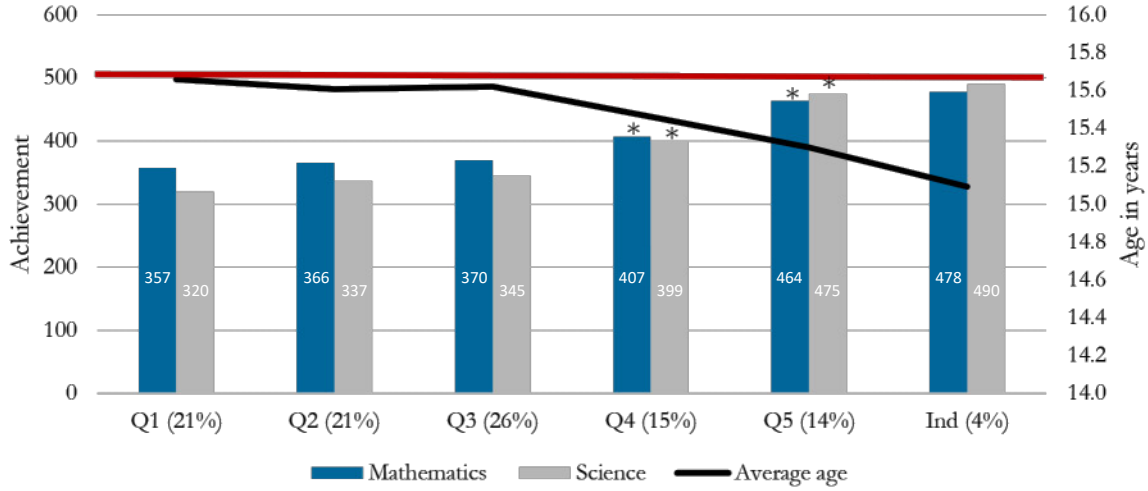
	WC	GT	FS	National	NW	KZN	NC	MP	EC	LP
Mathematics	441	421	396	389	383	378	377	375	366	364
GDP per capita (R000's)	98	111	80	82	77	66	80	78	55	59
Poverty Rate (%)	37.1	33.3	54.9	55.5	64.3	68.1	59.0	59.3	72.9	72.4
School Population (mil)	1.1	2.2	0.7	12.4	0.8	2.8	0.3	1.1	1.8	1.7

3.2. Mathematics and Science Achievement by School Poverty Index Rank, 2019

The South African schooling system has 95% of learners in public schools and 5% in independent schools (EMIS Data, 2020). Public schools are state controlled, while independent schools are privately governed. South African schools vary considerably with regard to possessed infrastructure and resources. The DBE calculated a poverty index for each public school according to the poverty of the community around the school, as well as, certain infrastructural factors. Public schools are categorised into five (unequal) groups, called quintiles, with Quintile 1 being the most under-resourced schools and Quintile 5 being the most resourced. Figure 4 sets out the average mathematics and science achievements for schools in each quintile category, as well as for independent schools.[2]

The mathematics and science achievements for learners in Quintile 1, 2 and 3 schools are similar (no significant differences are observed). Average mathematics and science achievements of learners in Quintile 4 schools (mathematics achievement 407 and science 399) are significantly different from the averages in both Quintile 3 and Quintile 5 schools. The average achievement of learners in Quintile 5 schools (mathematics achievement 464 and science 475) is not statistically different from the average achievement of learners in independent schools (mathematics achievement 478 and science 490). While the average achievement scores for learners in more affluent schools is higher than other schools, they have not yet reached the Centrepoint score of 500 (red line).

Figure 4: Average mathematics and science achievement and age by school poverty ranking, 2019



Learners in Quintile 1, 2 and 3 schools are older with an average age of 15.7 years, 15.6 years and 15.6 years respectively. The average age in Quintile 4 schools is 15.5 years. Learners are younger in Quintile 5 and Independent schools with an average age of 15.3 and 15.1 years respectively, suggesting there may be more Grade repetition in the Quintile 1,2 and 3 schools.

3.3. Mathematics and Science Achievement and Ability by Fee Status of Schools, 2019

With the high levels of household poverty in the country, the South African Schools Act of 1997 legislated the abolition of fees for learners attending schools in poorer communities. Government subsidises the school fees for learners in Quintile 1, 2 and 3 schools which are called 'no-fee' schools. Learners in Quintile 4 and 5 schools pay fees and the schools are designated as 'fee-paying'[3]. Learners in independent schools pay fees. Two-thirds of Grade 9 learners attend no-fee schools and one-third attend fee-paying schools.

The general description of learners in no-fee schools is that they come from lower income households, live in poorer communities, attend schools with fewer resources, and are largely taught by teachers with less specialist knowledge. Learners in fee-paying schools, on the other hand, come from largely

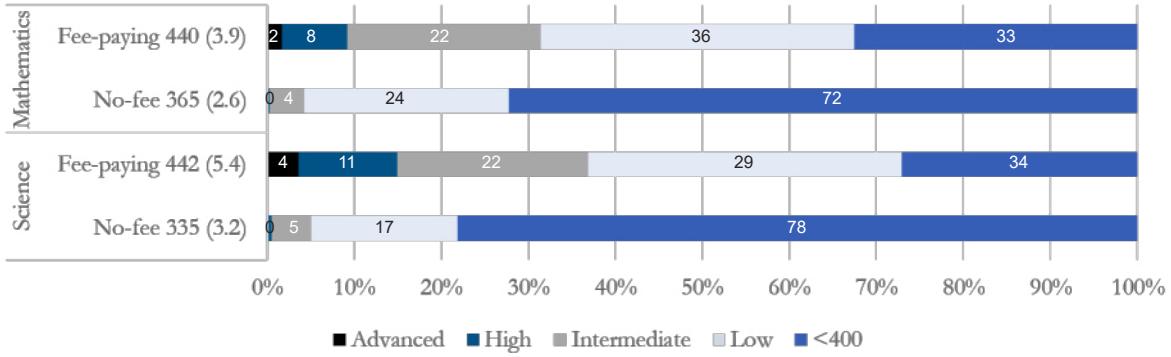
[2] We over-sampled the number of independent to 30 schools to provide reasonable estimates.

[3] There are a few Q4 and 5 schools where changing learner demographics led the province to also subsidise the school fees.

middle-class families, have better resourced homes, and attend schools with better qualified teachers and a climate that promotes better teaching and learning. The race demographics of learners in fee-paying schools has changed from previously all-White learners to the present demographics of 60% African, 20% Coloured, 14% White and 5% Indian learners.

Figure 5 reports the average achievement scores and ability levels for learners in fee-paying (Q4, 5 and Independent) and no-fee (Q1, 2 and 3) schools in TIMSS 2019.

Figure 5: Mathematics and science achievement at international benchmarks by fee-status, 2019



As expected, the differences in the material school and home conditions for learners attending fee-paying and no-fee schools leads to unequal achievements. Learners attending fee-paying schools achieve an average score of 440 (3.9) for mathematics and 442 (5.4) for science, and learners in no-fee school score 365 for mathematics and 335 for science. This means an achievement gap of 75 points for mathematics and 107 points for science between learners attending fee-paying and no-fee schools.

When the achievement scale scores are translated to ability levels, two out of three learners in fee-paying schools show they acquired basic mathematical and science knowledge. It is also noteworthy that in these schools 10% of mathematics learners and 15% of science learners achieve scores above the High Benchmark level (550) i.e., they have the ability to apply their mathematics and science knowledge in complex situations.

In no-fee schools, one in four learners showed they had acquired basic mathematical and science knowledge. It is particularly noteworthy that a small number of talented learners (0.25% mathematics and 0.45% science) achieve above the High Benchmark level.

3.4. TIMSS 2019 Mathematics and Science Achievement by Gender

International evidence on the relationship between gender and achievement is mixed, not only across countries but also within countries. The average achievement for girls is higher than for boys in both mathematics and science, but this difference is not statistically significant. This gender achievement pattern repeats in both fee-paying and no-fee schools. Figure 6 paints the picture of mathematics and science achievement by gender.

Figure 6: Mathematics and science achievement by gender, 2019

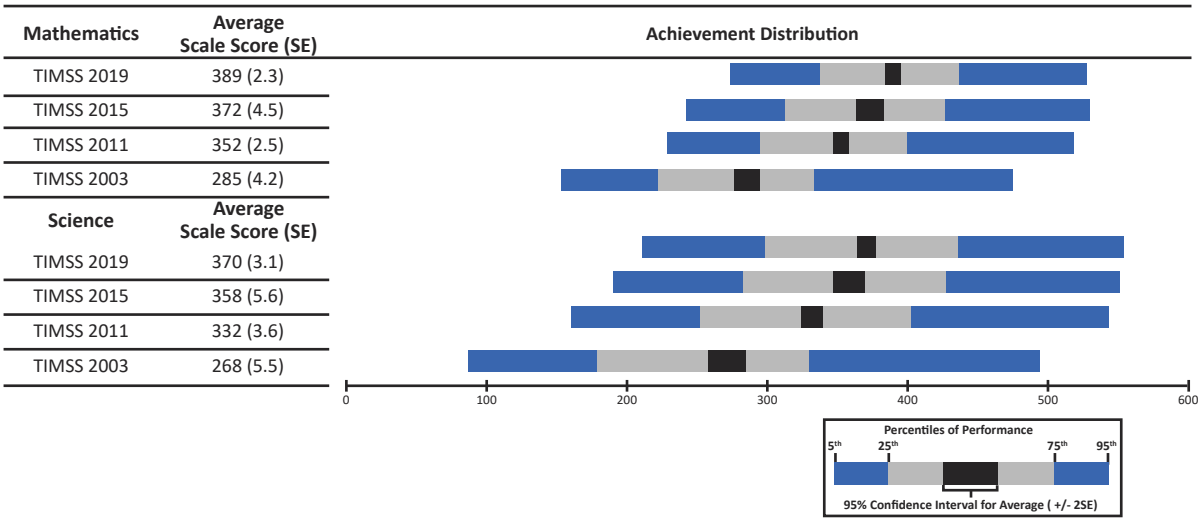
4. TREND OF MATHEMATICS AND SCIENCE PERFORMANCE

South Africa participated in TIMSS at the Grade 8 level in 1995, 1999 and 2003, and at the Grade 9 level in 2003, 2011, 2015 and 2019. TIMSS 2003 includes both Grade 8 and 9 learners and allows for an achievement trend measure from 1995 to 2019. This dataset is the only South African trend measure of 25 years of achievement. The TIMSS 2011 Highlights Report (Reddy et al., 2012) and the TIMSS 2015 Highlights Report (Reddy et al., 2016) provide the details of the achievement scores over the years. We extend the trend analysis with TIMSS 2019 data for national changes. For trends on local indicators, we will report for the 2011 to 2019 period only.

4.1. Trend of South African Mathematics and Science Achievement from (1995) 2003 to 2019

Our previous reports showed that the South African achievement for mathematics and science was the same in the TIMSS 1995, 1999 and 2003 cycles (Reddy et al., 2012). Between TIMSS 2003 and 2011, the mathematics and science achievement increased by 67 and 64 TIMSS points respectively. Between TIMSS 2011 and 2015, achievements increased by a further 20 TIMSS points for mathematics and 26 TIMSS points for science. This trend continued and between TIMSS 2015 and 2019: mathematics achievement increased by a further 17 points and science by 12 points. The achievement differences between the different cycles are statistically significant. Figure 7 illustrates the Grade 9 mathematics and science achievement for TIMSS 2003, 2011, 2015 and 2019 cycles.

Figure 7: Average mathematics and science achievement and scale score distributions, 2003 to 2019



Analysis of Figure 7 points to four noteworthy findings about the mathematics and science achievement changes from TIMSS 2003 to 2019.

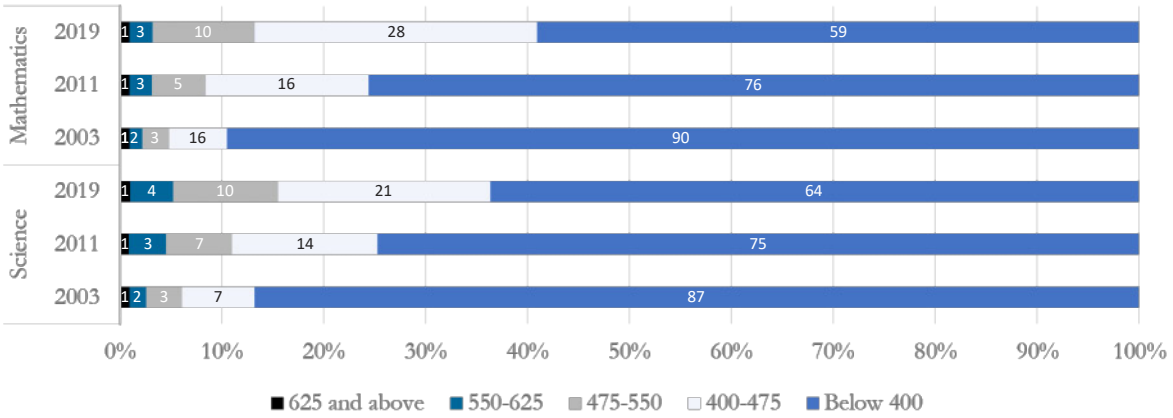
- From TIMSS 2003 to 2019, there was an achievement increase of 104 points for mathematics and 102 points for science. In 1994, with apartheid education, the country started from very low mathematics and science achievements. Twenty-five years into democratic rule the country recorded a one standard deviation increase in mathematics and science achievements.
- The best achievement gains continue to be at the lower end of the achievement distribution, meaning that those with the lowest achievement levels, generally from poorer households and in poorer schools, are improving the most.
- The achievement distribution (the difference of achievement at the 5th and 95th percentile) signals the extent of educational inequality in South Africa. Mathematics achievement inequality decreased from 3.2 SD in 2003 to 2.5 SD in 2019 and science achievement inequality decreased from 4.0 SD to 3.4 in the same period. There are higher levels of achievement inequality for science than for mathematics.

- TIMSS 2019 offers an opportunity to investigate achievement patterns over two eight-year periods: 2003 to 2011, and 2011 to 2019. The overall annual rate of achievement improvement from 2003 to 2019 is 6 TIMSS points. However, this achievement improvement rate is different for the two eight-year periods, 2003 to 2011, and 2011 to 2019. For mathematics, in the first period (2003 to 2011) the achievement improvement rate was 7.4 points per year and for the second period (2011 to 2019) the achievement improvement rate was 4.6 points per year. Similarly, for science the achievement improvement rate for the first period was 7.1 points per year and for the second period was 4.8 points per year. The slowing down of the achievement improvement rate means it would take the country longer to reach the achievement levels to which it aspires.

4.2. South Africa Trends in Mathematics and Science Abilities, 2003 to 2019

In line with increases in the mathematics and science achievements from 2003 to 2019, the mathematical and science abilities of learners also improved. The details of this increase are mapped in Figure 8 below.

Figure 8: Percentage of Learners Reaching International Benchmarks of Mathematics and Science, 2003 to 2019

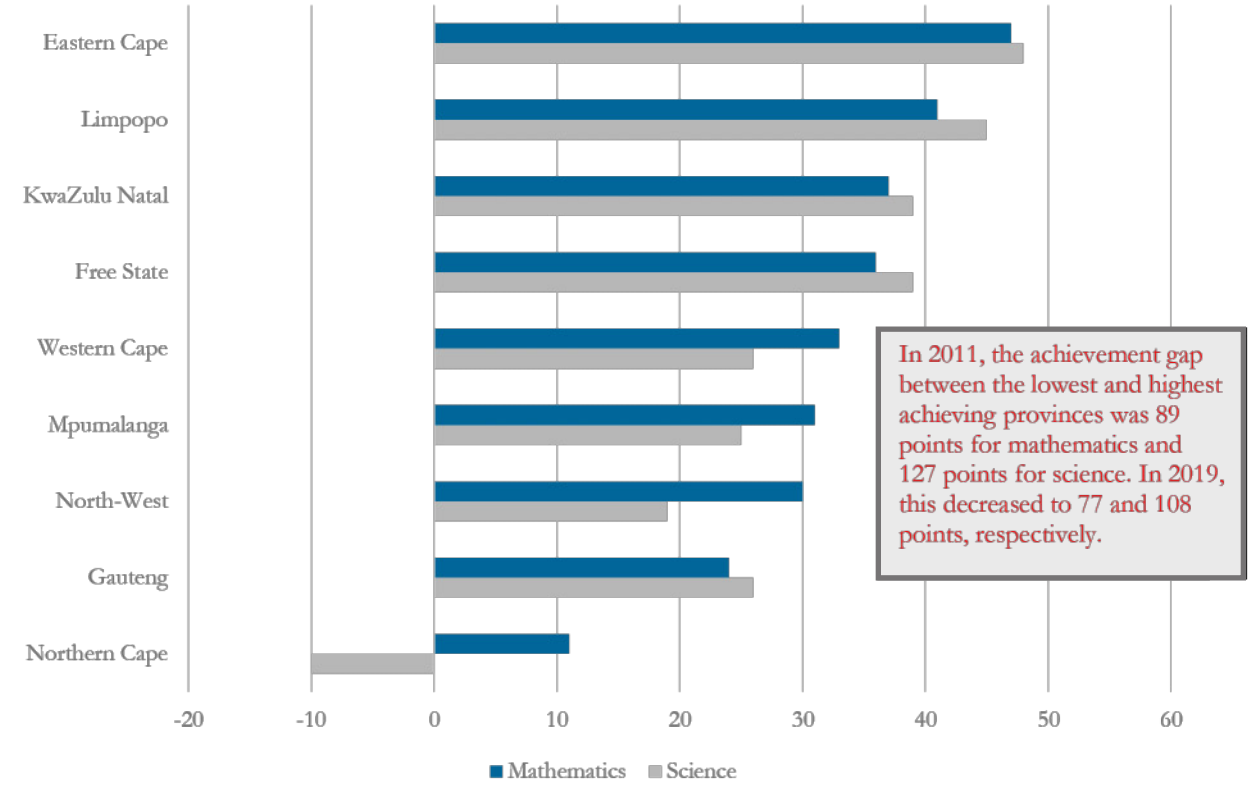


From 2003, with each subsequent TIMSS cycle, the percentage of learners demonstrating mathematics and science abilities at the different international benchmarks increased. In TIMSS 2003, South Africa started from a very low educational base with only 11% of mathematics learners and 13% of science learners acquiring basic mathematical and science abilities. In 2019, this increased almost fourfold for mathematics and threefold for science, with 41% of mathematics learners and 36% of science learners demonstrating basic mathematical and science abilities.

4.3. Trend in Mathematics and Science Achievement by Provinces, 2011 to 2019

In line with the improvements of the national achievements, we would expect the provincial mathematics and science achievement to improve. We calculated the achievement difference for each of the provinces, for the TIMSS 2011 to TIMSS 2019 period. Bars to the right of the "0" line in Figure 9 represent an increase in achievement from 2011 to 2019, while bars to the left represent a decrease in achievement. The length of the bar reflects the amount by which the provincial achievement has changed.

Figure 9: Change in average mathematics and science achievement by province, 2011 to 2019



The highest mathematics and science achievement improvements, over the 2011 to 2019 period, were for the two lowest achieving provinces: Eastern Cape (48 points for mathematics and science) and Limpopo (41 points for mathematics and 45 points for science). Northern Cape had the lowest achievement improvement for mathematics (+11 points) and decreased for science by 10 points. Our significance testing shows that the achievement difference, at the 95% confidence level, for all provinces between 2011 and 2019 is significant except for mathematics and science in the Northern Cape and science in the North-West. The science achievement difference, from 2011 to 2019, for Western Cape is significant at the 90% confidence level[4].

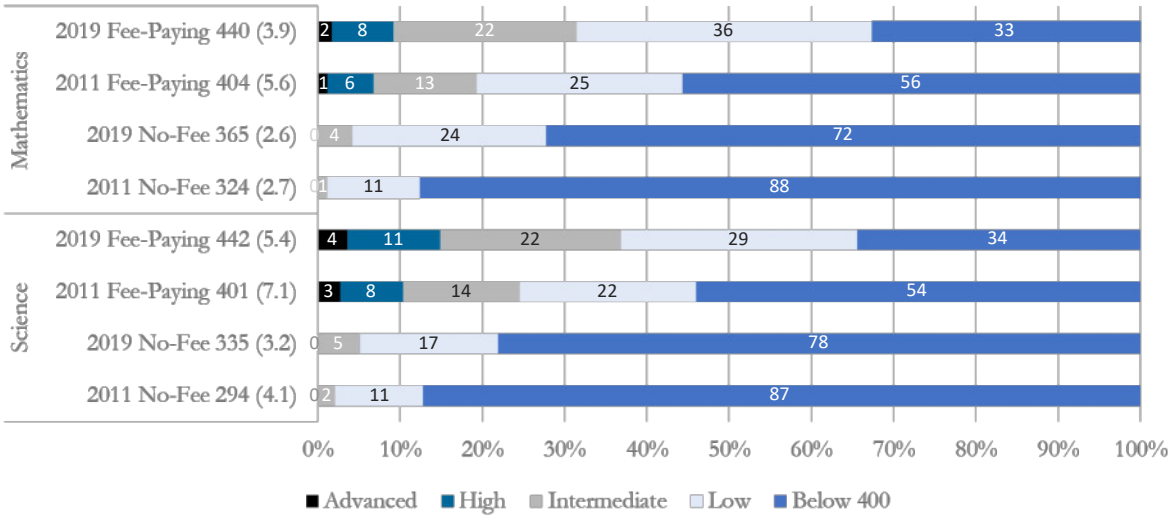
The achievement gap between the highest and lowest performing provinces decreased between 2011 and 2019. In 2011, the provincial achievement gap was 89 points for mathematics and 127 points for science. In 2019, the provincial achievement gap decreased to 77 points for mathematics and 108 points for science. The provincial achievement gap, though still wide, is decreasing slightly because of the improvements of the lowest achieving learners.

4.4. Trend in Mathematics and Science Achievement and Ability, by Fee Status, TIMSS 2011 to 2019

With the improved achievements at the national level from 2011 to 2019, we would expect changes in both fee-paying and no-fee schools. Figure 10 maps the details of how the achievement and ability measures changed in fee-paying and no-fee schools from 2011 to 2019.

[4] The caveat is that we must interpret all the achievement changes cautiously as the provincial sample sizes are small and standard errors are high

Figure 10: Mathematics and science achievement and percentage learners reaching the international benchmarks by fee-status, 2011 to 2019



The average science scores for learners in both fee-paying and no-fee schools, and for mathematics in no-fee schools, from 2011 to 2019 increased by 41 points. The mathematics average for learners in fee-paying schools improved by 36 points. The achievement gap between fee-paying and no-fee schools remained fairly constant at 80 points for mathematics and 107 points for science.

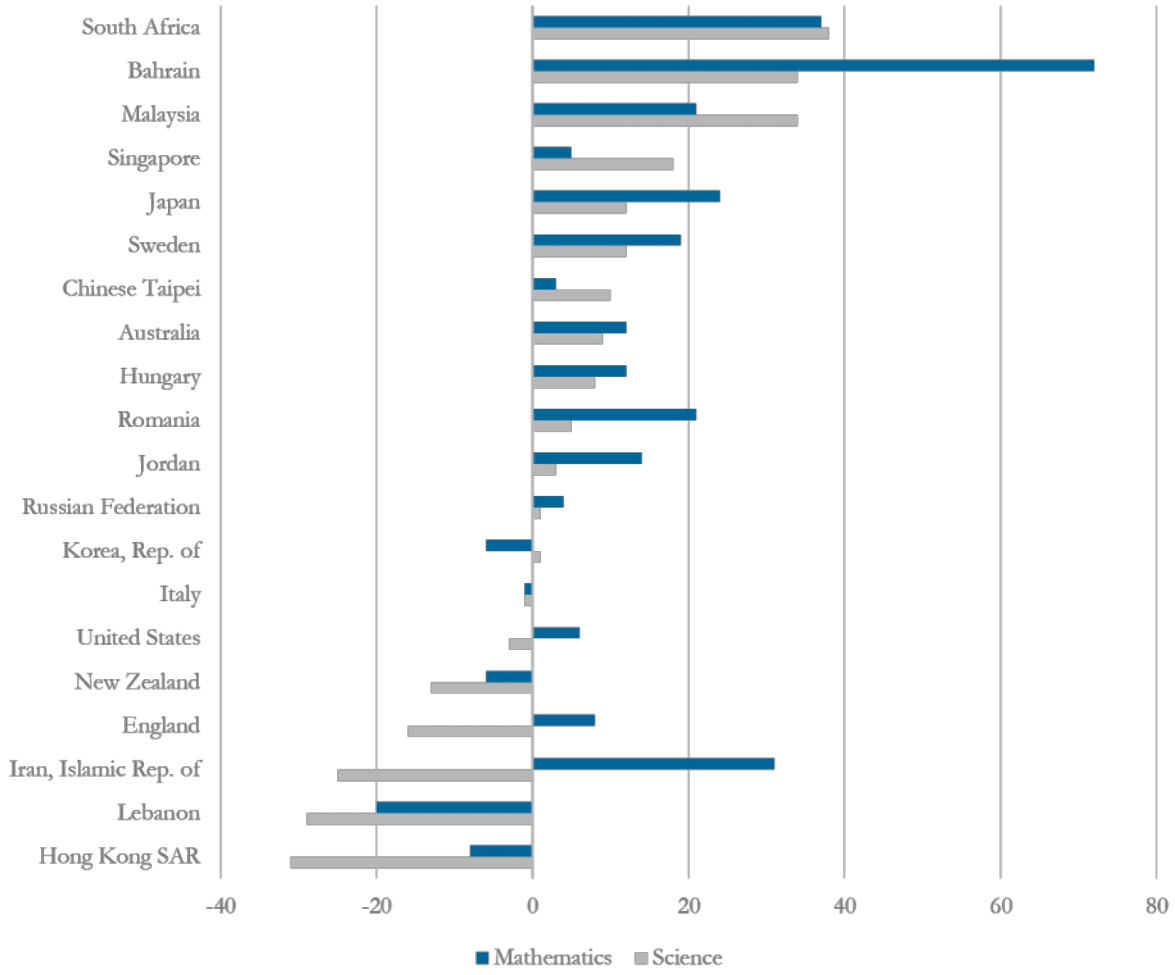
5. CHANGE IN MATHEMATICS AND SCIENCE ACHIEVEMENT BY COUNTRY, 2011 TO 2019

The TIMSS 2015 Highlights and National Reports reported on the differences in mathematics and science achievements for the 25 countries that participated in both TIMSS 2003 and TIMSS 2015. We continue this analysis with 20 countries (from the original 25) who participated in both TIMSS 2011 and 2019.

Again, bars to the right of the "0" base line in Figure 11 represent an increase in achievement from 2011 to 2019, and bars to the left represent a decrease in achievement. The length of the bar reflects the amount by which the country achievement has changed.

Of the 20 countries included in this analysis, 15 improved in mathematics achievement between the two cycles and five decreased. For science, 13 countries improved and there was an achievement decrease for seven countries. From 2011 to 2019, South Africa has shown the biggest positive change for science with an achievement improvement of 38 points. For mathematics, South Africa showed the second-best improvement of 37 points, after Bahrain.

Figure 11: Change in mathematics and science achievement by country (2011-2019)



SECTION C: EXPLAINING MATHEMATICS AND SCIENCE ACHIEVEMENT

6. UNEQUAL HOME CONDITIONS AND ACHIEVEMENT

In an equal and fair world, educational outcomes would be dependent on ability and effort. In a context of inequality, however, as in South Africa, personal conditions, such as where one lives, influence achievement outcomes. Research shows a strong, positive relationship between achievement and socio-economic status, including parental education. TIMSS 2019 data, from learners, about possessions and educational resources in their homes allows us to explore the relationship between their socio-economic environment and TIMSS achievement.

Figure 12 reports the percentage of learners who have, what we categorized, as basic, educational or digital assets. These assets are a proxy measure of a home environment that supports learning. Having these assets is positively associated with higher mathematics and science achievement. We report the availability of these assets, firstly at the national level, and then for learners in fee-paying and no-fee schools.

Figure 12: Percentage of learners having basic, educational and digital assets at home, 2019

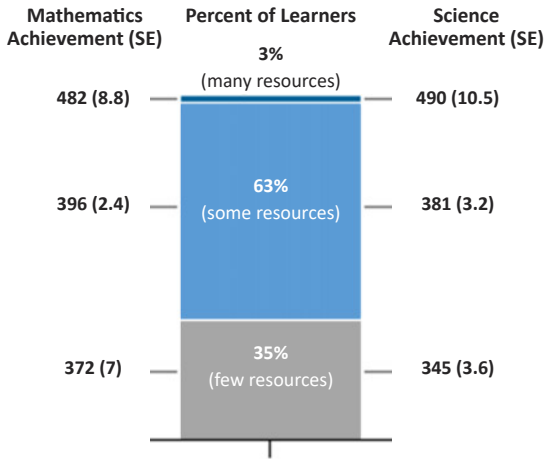
Asset Type	Possession	National	Fee-paying	No-fee
Basic	Running tap water*	73	90	65
	Flush toilet*	60	91	44
Educational	Parents: Post-Secondary Education*	38	48	34
	Over 25 books in the home*	18	27	13
	Own room*	68	72	66
	Always/almost always speak test language at home*	28	51	16
Digital	Internet connection*	41	59	32
	Computer or Tablet*	48	69	37

**Difference in availability of assets in fee paying and no-fee schools is statistically significant*

There are significant differences in the availability of all assets for learners in fee-paying and no-fee schools. In no-fee schools, a third of learners (35%) still lack running tap water and over half of learners (56%) do not have flush toilets in their homes. Access to basic amenities is critical for learners to participate successfully in education.

Although the availability of home educational resources is low for the majority of learners, the absence of these resources is much higher in no-fee schools and negatively affects learning outcomes. Parental education is a signal of the wealth and social capital of the household and has strong positive links with learner achievement. Half the learners (48%) in fee-paying schools lived in a home where at least one parent had a post-secondary education (diploma or degree). In no-fee schools, the parents of one third of learners (34%) had the same education level. Learners who speak the language of the test at home will have better linguistic access to the TIMSS assessment and be able to respond more successfully. Half the learners (51%) in fee-paying schools reported always or almost always speaking the language of the test at home, compared with just 16% in no-fee schools. In a world where digital learning is becoming more important, only half (48%) of South African learners have such digital hardware and 41% have an internet connection at home. These conditions are worse for the learners in no-fee schools than in fee-paying schools.

Figure 13: Percentage of learners with home educational resources and achievement, 2019

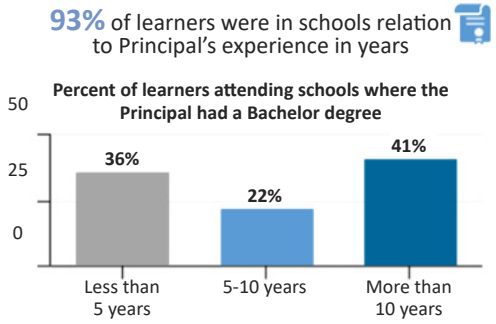


TIMSS has constructed a Home Educational Resources Scale from learner reports summarizing the availability of (i) books in the home, (ii) home study supports (own room and internet connectivity), and (iii) highest level of education of either parent. Figure 13 shows the proportion of learners with each level of home resources available to support educational achievement and the association with mathematics and science achievement. Only 3% of learners reported having 'many' home educational resources (compared to 14% internationally). There is a significant positive association between the availability of home educational resources and mathematics and science achievements (see achievement scores on the diagram on the left).

7. SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

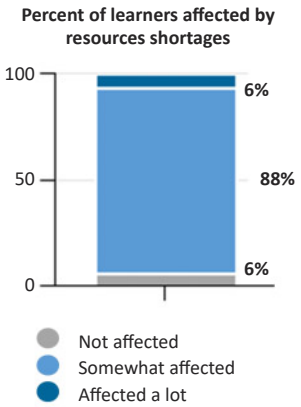
In contexts of high household poverty levels, parents and the society view schools and classrooms as the institutions to equalise opportunities for learners from poorer homes and attempt to level the playing field of educational success. Successful schools have competent school leadership, sufficient human and economic resources, are more likely to have safe and orderly working and learning environments, and learners who come from better resourced homes.

SCHOOL LEADERSHIP



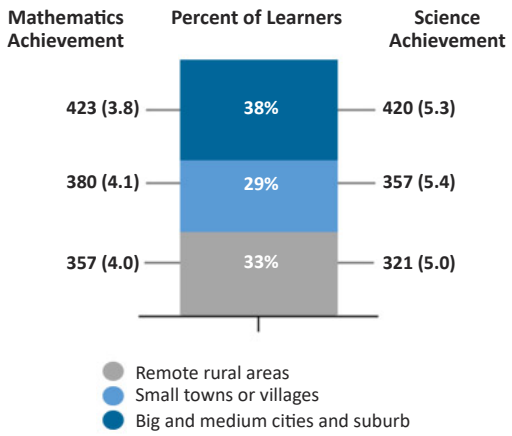
The Principal sets the educational tone in a school and plays a central role in managing educators, learners and resources. Extant literature points to significant links between the principal's qualifications and experience, as well as leadership style and learner achievement. Eighty (80) percent of learners attended schools where the principal's qualification is a Bachelor degree, 13% with a principal having a postgraduate degree, and 7% attended schools where the principal did not have any degree qualification. On average, learners attended schools where the principal had nine years of experience.

RESOURCES



The resources available in the school and its classrooms influence instruction, learning, and subsequently, achievement. Principals rated how instruction in the school was hindered by 13 resource shortages, constituting the *Instruction Affected by Mathematics and Science Resource Shortage* scale. Only a small number of learners (between 6 and 7%) attended schools with adequate resources (compared to 26% internationally) and they achieve significantly higher mathematics and science scores. Learners who were not affected by resource shortages achieved significantly higher mathematics achievements than those affected a lot by resource shortages. There is a similar pattern for science. Mathematics achievement was 477 in schools not affected by resource shortage in comparison to 386 where they were affected a lot.

LOCATION



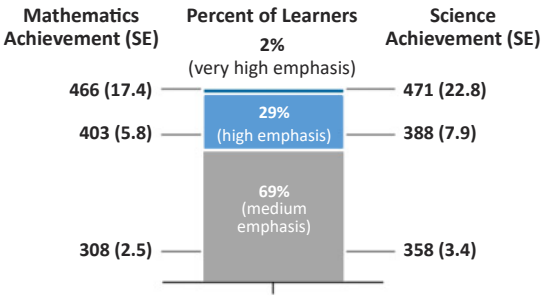
The schools spatial location is a proxy of the socio-economic status of most learners. South Africa is a large and spatially diverse country. Learners and schools in rural remote areas will generally be poorer while schools in big cities and suburbs will have better resources.

Learners attending schools in big and medium size cities and suburbs attain significantly higher achievements than those attending schools in villages or remote rural areas. Mathematics learners in urban schools scored 423 in comparison to 357 in remote rural areas.

8. SCHOOL CLIMATE PROMOTING ACADEMIC ACHIEVEMENT

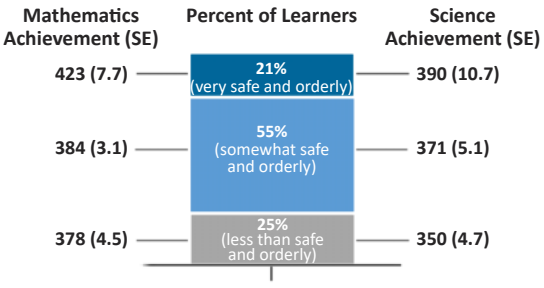
Learners with higher achievements typically attend schools with a positive school climate that emphasise academic success, and are safe and orderly spaces for both learners and educators.

SCHOOL EMPHASIS ON ACADEMIC ACHIEVEMENT



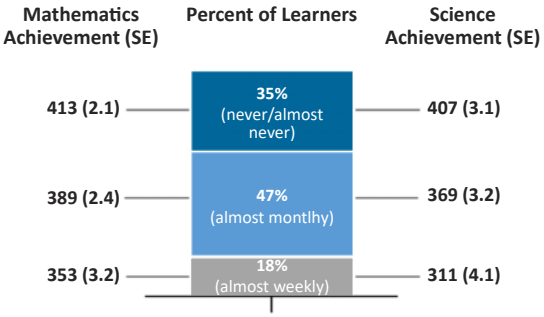
Principals responded to a set of 11 items constituting a *School Emphasis on Academic Success* scale. Three in ten South African learners attended schools with a higher emphasis on academic achievement, and seven in ten learners were in schools with limited emphasis. This compares to six in ten internationally. Learners in schools that emphasised academic success achieve significantly higher mathematics and science scores (mathematics score of 466 for learners experiencing very high emphasis in comparison to 380 for medium emphasis).

SAFE AND ORDERLY SCHOOLS



Mathematics and science educators rated their schools on eight statements, for a *Safe and Orderly* Schools scale. One in five South African learners attended schools rated as 'very safe and orderly' (compared to one in two internationally). Learners in schools that have a higher safety and orderly rating achieve significantly higher mathematics and science scores (mathematics score is 423 in very safe and orderly schools in comparison to 378 in less than safe and orderly schools).

BULLYING

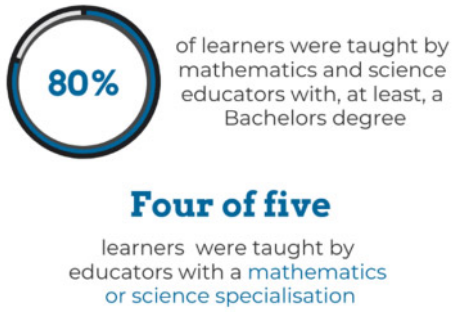


Learners responded to eleven statements on how often they experienced bullying behaviours (physical, verbal or through digital devices) from their school peers to create a *Student Bullying* scale. South Africa experienced higher levels of bullying than most other participating countries. A total of 35% of South African learners reported 'never or almost never' being bullied, as compared to the international average of 71%. Learners bullied more often have significantly lower mathematics and science achievement than those hardly bullied. Learners who were hardly bullied scored 413 in mathematics in comparison to 353 for those bullied a lot.

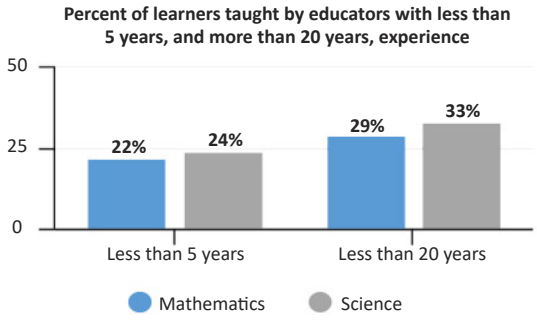
9. CLASSROOMS: EDUCATORS AND RESOURCES

Successful learning is likely to be influenced by the calibre of educators, the quality of the classroom environment and instructional activities, as well as the resources available to support instruction. We will report on (i) Educators and (ii) Resources and Materials available to support instruction.

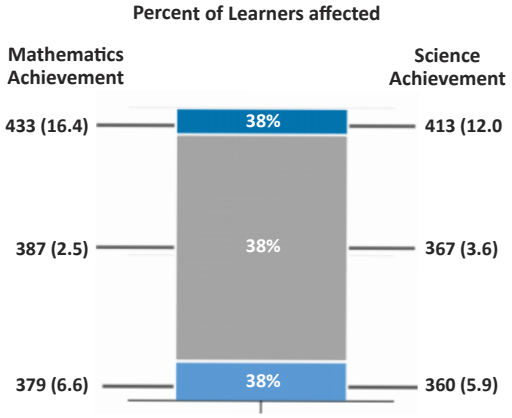
9.1. Educator Preparation, Experience and Challenges



Educators with the requisite subject knowledge and experience contribute to higher mathematics and science achievements. Educators with, at least, a Bachelor degree taught 80% of mathematics and science learners. Educators with a tertiary diploma taught 20% of learners. Of those with a Bachelor qualification, 83% reported a mathematics specialisation and 79% a science specialisation. Internationally, educators with at least a Bachelor degree taught 96% of mathematics and science learners.



The average teaching experience is 14 years for mathematics educators and 15 years for science educators. Educators with less than 5-years of experience taught 22% mathematics and 24% science learners. Educators with over 10-years of experience taught the majority of learners (57% mathematics and 64% science). There is no significant association between years of experience and achievement.

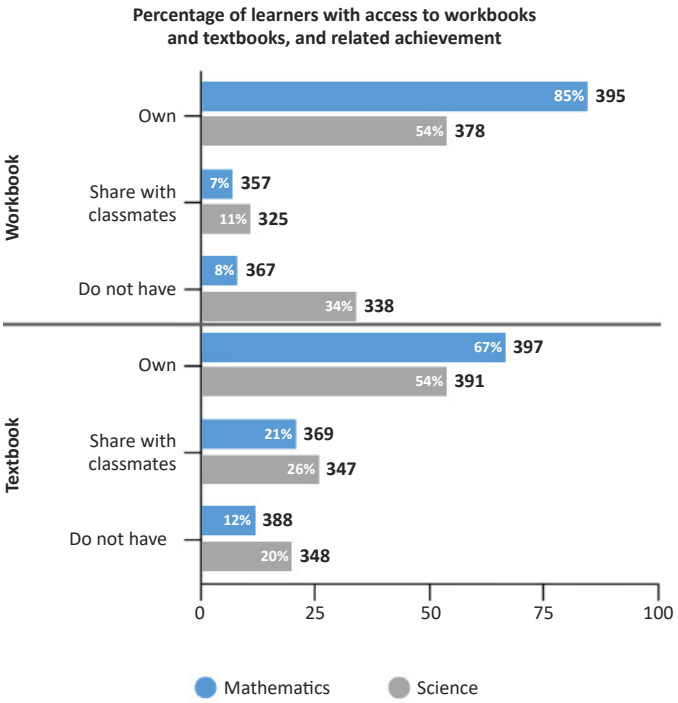


Educators reported on eight attributes about the extent to which teaching is limited by learners not being ready for instruction (e.g. lacking pre-requisite skills, nutrition, sleep etc) on the *Classroom Teaching Limited by Students Not Ready for Instruction scale.*

Only a small number of learners (8%) were unaffected ('very little") and deemed to be ready for instruction. They achieve significantly higher mathematics and science scores than those affected 'a lot' or 'some'. The mathematics scores of learners ready for instruction were 433 in comparison to 379 that were least ready.

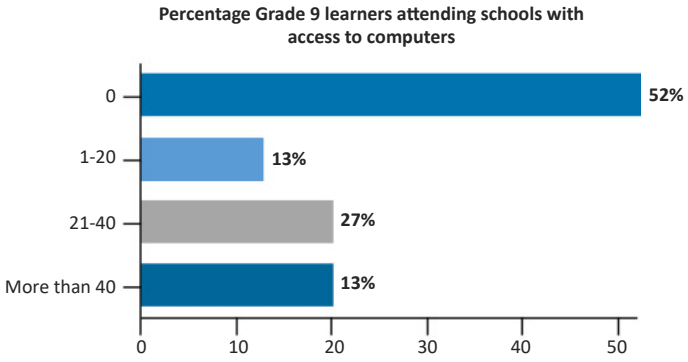
10. MATHEMATICS AND SCIENCE RESOURCES AND MATERIALS

Having sufficient instructional resources and materials is important for a favourable learning environment and the provision of quality instruction.



The state has invested to provide learners with mathematics and science workbooks and textbooks. Most learners either own or share a mathematics workbook (92%) or textbook (88%). Two thirds of learners (65%) have their own or share a science workbook (65%) and 80% own or share a science textbook.

Learners who have their own textbook or workbook achieve significantly higher mathematics and science scores than those who share or do not have workbooks and textbooks. Mathematics learners who have their own workbooks score 395 in comparison to 357 for those who share.



Pre-Covid-19, educational systems invested in digital technology to promote learning. The coronavirus pandemic placed the spotlight on digital learning and highlighted the inequalities in access to digital resources.

According to principals, half the Grade 9 learners do not have access to computers, one third of Grade 9 learners have between 1 and 40 computers, and 13% have over 40 computers.

SECTION D: KEY FINDINGS

This report has provided a contemporary, and 25-year historical, perspective of South African mathematics and science achievement in an international assessment. In this final section we draw together the main findings from the most recent analysis.

Findings from mathematics and science achievement data

TIMSS offers the dual opportunity to benchmark South African mathematics and science achievement against other participating countries, and to monitor our achievement over time.

1. **Achievement and ability in TIMSS 2019:** Of the 39 countries that participated in TIMSS 2019, South Africa continues to attain lower mathematics and science achievements. The South African TIMSS 2019 mathematics score of 389 (SE 2.3) and the science score of 370 (3.1) is an increase of 17 points for mathematics and 12 points for science from the previous TIMSS 2015. The increase is statistically significant at the 95% level for mathematics, and at the 90% level for science.

   The TIMSS achievement scores can describe mathematical and science abilities. Forty one (41) percent of mathematics learners demonstrated that they had acquired basic mathematical knowledge, and 36% of science learners had acquired basic science knowledge.

2. **Achievement and ability trends:** South African mathematics and science achievement averages have improved from 'very low' (1995, 1999 and 2003) to 'low' (2011, 2015 and 2019). From 2003 to 2019, the mathematics and science achievement increased by one standard deviation (104 points for mathematics and 102 points for science). In 2003, only one in ten learners demonstrated that they had acquired basic mathematical and science knowledge. This increased to four in ten learners in 2019.

3. **Pace of achievement improvement:** While the improvement in educational achievement is recognised, the concern is that the rate of improvement is decreasing. The improvement rate for mathematics and science achievement for the 2003 to 2011 period was 7.4 points and 7.1 points per year respectively (67 points for mathematics and 64 points for science over this period)[5]. However, for the 2011 to 2019 period these figures fall to 4.6 points and 4.8 points per year (an improvement of 37 points for mathematics and 38 points for science over this period). In order to meet the country's developmental objectives, the Medium Term Strategic Framework (2019– 2024) set the target for the TIMSS average mathematics score of 420 and the average science scores of 420 by 2023, at the Grade 9 level. In order to meet these targets will require additional effort from all education role players to accelerate the pace of improvement.

4. **Achievement gaps:** South African achievement continues to be unequal and socially graded. On the one hand achievement gaps, though decreasing, continue to be linked to socio-economic backgrounds, spatial location, attending fee-paying versus no-fee schools, and the province of residence. This confirms the well-known narrative that advantage begets advantage, and home disadvantages continue to impede schooling. On the other hand, the highest achievement increases are from the lowest performers. This means that the lowest achieving provinces have improved the most over the long-term period. Another dynamic that contributes to achievement equity is that the demographic profile in Quintile 4 and 5 schools has increased to 60% African learner participation.

[5] This was over a 9 year period

5. **Gender gaps:** The mathematics and science achievement scores are higher for girls than for boys, but this gender difference is not statistically significant. We must recognize the overall underperformance of boys as a concern.

6. **Science human capabilities:** The changing South African economy has a higher demand for high-skilled tertiary education graduates, especially in Science, Engineering and Technology (SET) subjects. The increased proportion of Grade 9 learners demonstrating improved abilities in mathematics and science could increase the mathematics and science pipeline to the exit level matriculation examination, and further into tertiary studies.

   It is noteworthy that 13% of mathematics learners and 15% of science learners reached the intermediate benchmark (learners have and can apply knowledge) levels. In order to meet the needs of our society and economy, policy should focus on two objectives: striving for equity by decreasing the achievement gap, and striving for increased proportions of higher performance by improving the achievement standard for all learners.

Findings from curriculum data (see the Curriculum Analysis Highlights Report)

7. Science achievement is lower than mathematics achievement, and the wider science distribution points to higher levels of science variance. The much lower minimum science scores suggest additional challenges having an impact on the teaching and learning of science (e.g. language, resources and educator knowledge). In addition to mathematical improvement programmes, national and provincial authorities must focus on the science subjects.

8. Two thirds of the TIMSS assessment items require learners to use higher cognitive skills of application and reasoning for success. The South African assessment framework has a greater focus on the skills of knowing and solving routine problems, and there is limited emphasis on the skills of applying and reasoning. The level of school and national assessments should include more assessment items at higher cognitive levels.

9. Learners performed better in items that required them to select a response (multiple choice question) than in items where they had to write a response (constructed response). Learners were unable to coherently write descriptions or explanations. The national reading strategy should be expanded to become a reading and writing strategy.

Findings from contextual data

Many home, school and classroom factors influence mathematics and science achievement. Parents and society expect schools and classrooms to ameliorate home disadvantages.

10. Home conditions continue to be unequal, and some homes are still not conducive to learning activities. Learners from homes lacking the basic amenities, such as running tap water and flush toilets, have the lowest educational outcomes. In order to increase achievements the starting point for some learners is improved home conditions.

11. The educational qualifications of both principals, and mathematics and science educators, has improved over time. Currently, over 80% of learners are in schools where the principal, mathematics and science teacher had, at least, a Bachelor qualification. The majority of educators indicated a specialisation in mathematics or science. Compared with other countries, South African educators attended the highest number of professional courses. However, learners' mathematics and science achievements do not match the level of tertiary education and the extent of professional development courses that educators have attended. Education and training is a massive investment, and the quality of this investment must be investigated and strengthened.

12. The climate of the school counts. Schools with a healthier climate (higher emphasis on academic success, fewer disciplinary problems and incidences of bullying, more safe and orderly schools) have higher achievements. Compared with other countries, South African schools experienced higher levels of disciplinary, safety and bullying problems. Improving the school climate will be dependent on what happens both within the school and the community surrounding the school.

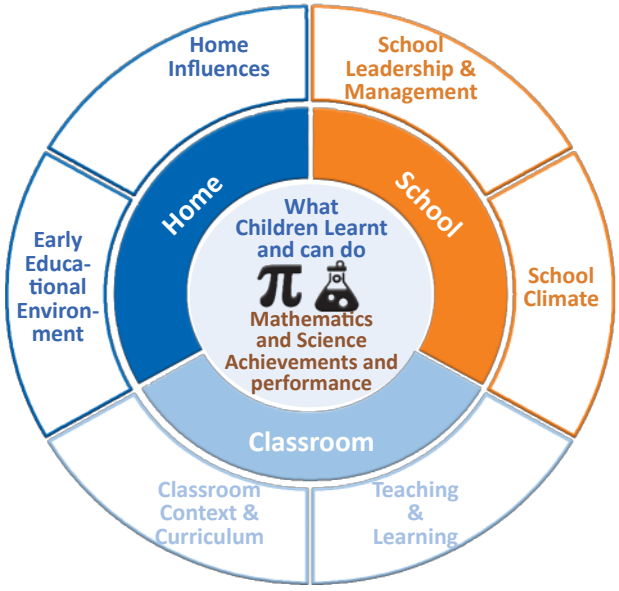
13. Resources matter for educational success. Principals, educators and learners responded to questions about resource shortages. Learners achieve higher results in schools with better resources. As a starting point, all learners must have their own mathematics and science workbook and textbook.

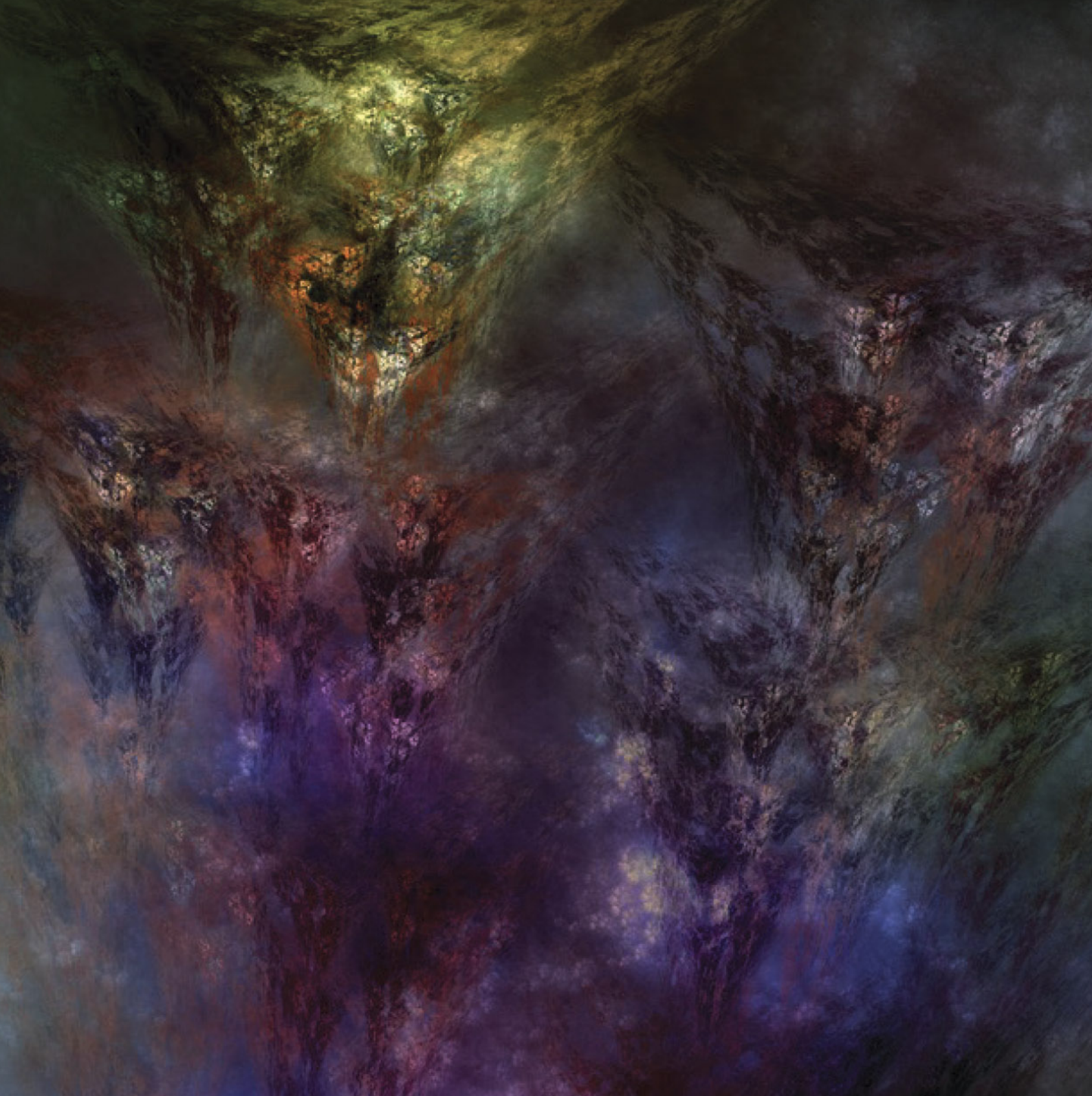
    As the world moves toward digital platforms for learning, South Africa falls far short of adequate access to digital resources in both homes and schools. Half of South African homes and Grade 9 classes do not have access to a computer. This will further disadvantage South African learners.

Notes

TIMSS Conceptual Framework

TIMSS uses the curriculum as the organising principle of how educational opportunities are provided to learners. The curriculum model has three aspects: (i) the intended curriculum, (ii) the implemented curriculum and (iii) the attained curriculum. The intended curriculum refers to the mathematics and science knowledge that society intends learners to learn; the implemented curriculum refers to how the educational system is organised (curriculum coverage) and the attained curriculum refers to what learners have learnt (learner achievement scores).





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