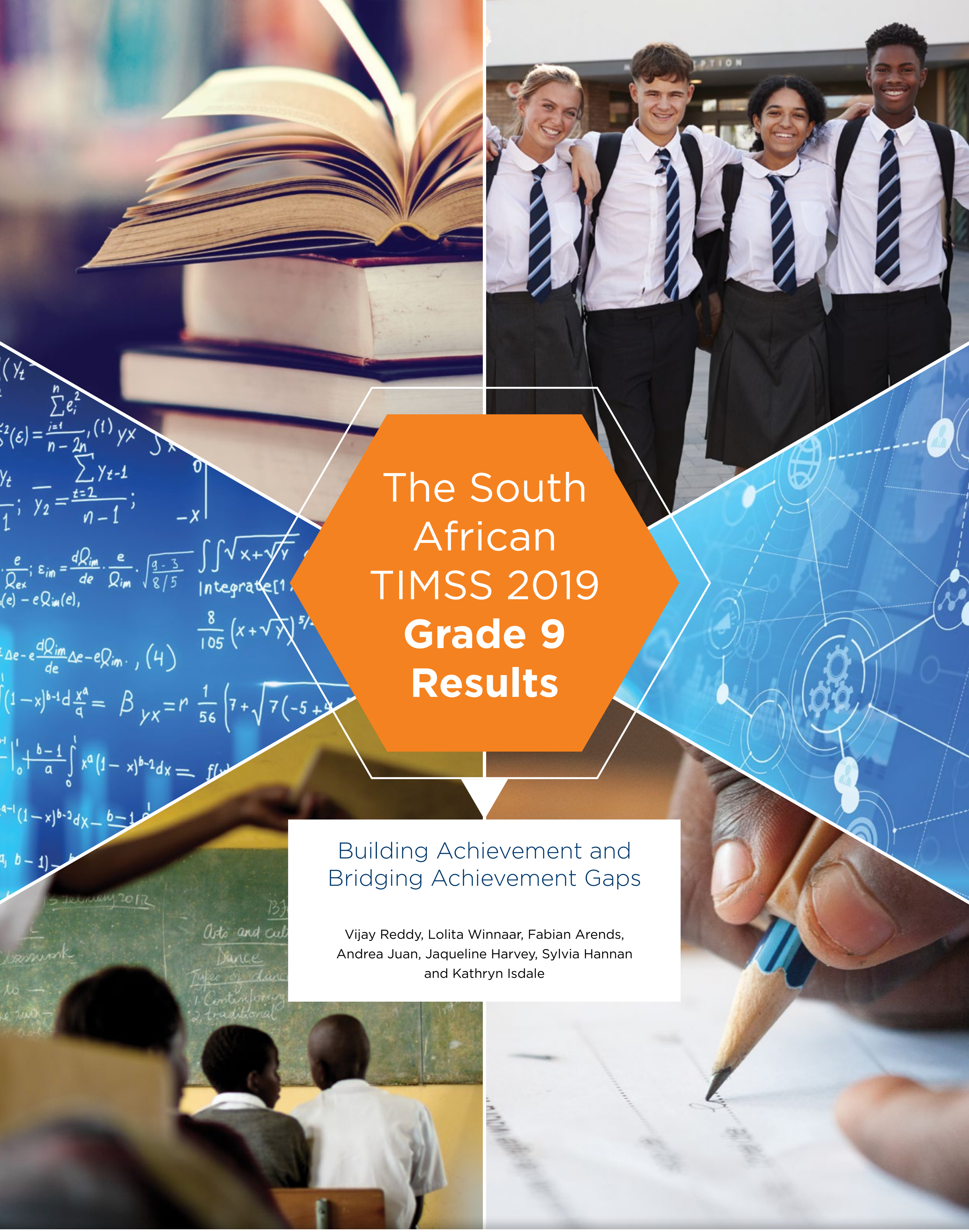

The South African TIMSS 2019 **Grade 9 Results**

Building Achievement and Bridging Achievement Gaps

Vijay Reddy, Lolita Winnaar, Fabian Arends, Andrea Juan, Jaqueline Harvey, Sylvia Hannan and Kathryn Isdale

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TIMSS National Research Coordinator
Human Sciences Research Council

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LIST OF ACRONYMS

CAPS	Curriculum and Assessment Policy Statements
DBE	Department of Basic Education
DME	Data Management Expert
DPME	Department of Performance Monitoring and Evaluation
GDP	Gross Domestic Product
GHS	General Household Survey
GNI	Gross National Income
HER	Home Educational Resources
HSRC	Human Sciences Research Council
IEA	International Association for the Evaluation of Educational Achievement
IRT	Item Response Theory
LoLT	Language of Learning and Teaching
MCQ	Multiple Choice Question
MTSF	Medium-Term Strategic Framework
NCS	National Curriculum Statement
NDP	National Development Plan
NEIMS	National Education Infrastructure Management System
OECD	Organisation for Economic Co-operation and Development
PIRLS	Progress in International Reading Literacy Study
RSA	Republic of South Africa
SE	Standard Error
SES	Socioeconomic Status
SGB	School Governing Body
StatsSA	Statistics South Africa
TIMSS	Trends in International Mathematics and Science Study
WinW3S	Within-school Sampling Software

READER'S GUIDE

The following are key concepts that are used within the report. Their definitions are provided here for easy referral.

TIMSS ACHIEVEMENT

TIMSS describes performance in two ways. The first is through achievement scale scores while the second is by translating these scale scores into international achievement benchmarks.

TIMSS achievement scale score: Each learner responds to only a subset of the TIMSS assessment items as the full item bank is too large. TIMSS therefore utilises Item Response Theory (IRT) in combination with population modelling to provide estimated achievement scores as though each learner had answered all items. The IRT or scale score is calculated by considering whether a learner answered the set of items administered correctly as well as the difficulty level of the item.

Learners complete their allocated assessment items and their scores on these items are combined with the demographic background of similar learners to calculate estimated scores for the full assessment. Five estimates, or plausible values, for each learner are drawn.

Plausible values indicate what the individual learner would have achieved for the entire assessment had they completed it.

The TIMSS achievement scale is summarised on a 0 to 1 000 scale, with a centrepoint of 500 and a standard deviation of 100. This report thus uses scale score to refer to learner achievement.

International achievement benchmarks are used to describe the abilities learners demonstrate (i.e. what learners know) at particular points on the achievement scale. TIMSS describes four points on the scale in terms of ability: Low (400 to 475 points); Intermediate (475 to 550 points); High (550 to 625 points); and Advanced (>625 points). For South Africa we included the descriptor 'Very Low' for average scores of less than 400 points.

HOW LEARNERS WERE ASSESSED

TIMSS cognitive domains: The three hierarchically organised cognitive domains are knowing, applying and reasoning. Knowing covers the facts, concepts, and procedures learners need to know. Applying focuses on the ability of learners to apply knowledge and conceptual understanding to solve problems or answer questions. Reasoning goes beyond solving routine problems to encompass unfamiliar situations, complex contexts, and multistep problems.

READING GRAPHS AND TABLES IN THE REPORT

Distribution or percentile graph: A percentile indicates the value in the distribution of scores below which a percentage of the population can be found. For example, if the 5^{th} percentile of the distribution is 200, this means that 5 percent of the distribution will be below 200 and 95 percent of the distribution surpasses this value. The TIMSS distribution graphs are drawn from the 5^{th} to the 95^{th} percentile with the confidence interval shown as well (see diagram that follows). The far-left side of the graph marks the 5^{th} percentile. This represents the point below which five percent of the assessed learners scored. The first dark blue section of the bar covers the range between the 5^{th} and 25^{th} percentiles. The first light blue section shows the range of scores between the 25^{th} percentile and the lower limit of the confidence interval for the average score. The right-hand side of the graph is read similarly, where the light blue section represents the scores between the upper limit of the confidence interval and the 75^{th} percentile, and the dark blue section shows the scores between the 75^{th} and 95^{th} percentiles.

The **achievement distribution inequality** within countries is defined as the score difference between the 5th and 95th percentile.

Item percent graph: Each dot on the graph represents the percentage of correct responses for the corresponding item. The more difficult items, with fewer learners answering correctly, are on the left-hand side of the graph; and the less difficult items, with a higher percentage correct, are on the right-hand side.

Decimals were rounded off to whole numbers which may mean that some values in figures and tables may not exactly add to the totals.

IMPORTANT STATISTICAL TERMS

Statistical significance: When a finding is significant it means that there is confidence that the finding is real and not a result of chance. We used the *t*-statistic for significance testing and report findings at the 95 percent confidence level.

Standard error (SE): The standard error tells us how accurate the mean of any given sample is likely to be compared to the true population mean. The average scale score is calculated from the achievement of the sampled learners and is an estimation of the average score for the population if all Grade 9 learners in the country were to have written the assessment.

Confidence interval: The confidence interval (CI) is a range of values that you can be 95 percent confident contains the true mean of the population. The confidence interval is calculated as a range from -1.96 SE to +1.96 SE.

Bivariate analysis: Statistical analysis determines whether there is a relationship between two variables.

Multivariate analysis: Statistical analysis that determines whether there is a relationship between two or more variables and a specific outcome.

DEFINITIONS OF BACKGROUND CHARACTERISTICS

Basic education refers to schooling from Grade R to Grade 12 and is divided into four phases: Foundation Phase (Grade R to 3); Intermediate Phase (Grade 4 to 6); **Senior Phase (Grade 7 to 9)**; and Further Education and Training Phase (Grade 10 to 12).

School quintile: A poverty index was calculated for each public school. These schools are categorised into five (unequal) groups, called quintiles, with Quintile 1 being the most under-resourced schools in the most economically disadvantaged communities, and Quintile 5 being the best resourced schools in more affluent communities.

No-fee and fee-paying schools: Learners in Quintile 1, 2 and 3 schools are exempt from paying school fees and are referred to as no-fee schools. Learners in Quintile 4 and 5 schools pay school fees. Learners attending independent schools also pay school fees. In this report we combined the Quintile 4, 5 and independent schools and refer to them as fee-paying schools.

EXECUTIVE SUMMARY: SOUTH AFRICAN TIMSS 2019 GRADE 9 RESULTS

The Trends in International Mathematics and Science Study (TIMSS) assesses mathematics and science knowledge of fourth and eighth grade learners around the world. South Africa has participated in six of the seven TIMSS cycles (1995–2019), at the eighth or ninth grade, providing a rich dataset spanning 24 years. Participation in TIMSS allows countries to evaluate their learners' achievements and compare their achievements with other countries, as well as to monitor the health of their education systems over time. In addition, the study allows the exploration of how various contextual factors are associated with mathematics and science achievement.

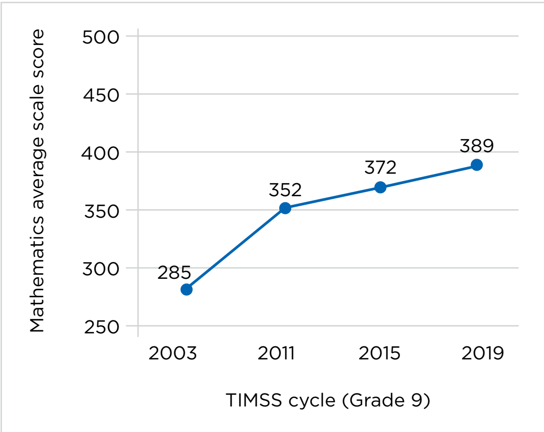
In August 2019, we collected achievement and contextual data in 519 schools from 519 principals, 543 mathematics and science educators, and 20 829 learners. The results of this TIMSS 2019 Grade 9 study are presented in this report.

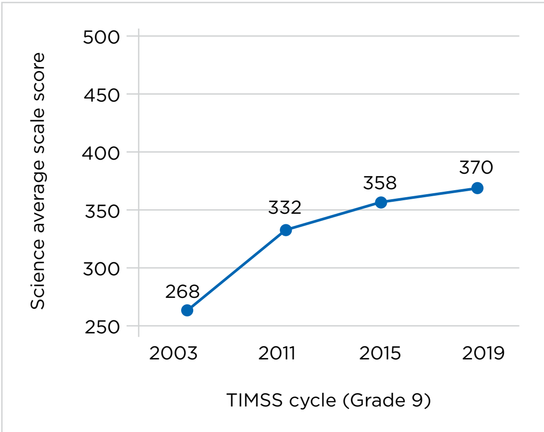
Findings from previous TIMSS cycles show that South African educational performance outcomes have improved, although they are still low and unequal. Achievement gaps continue to be linked to socioeconomic backgrounds and school contexts. The TIMSS 2019 results extend our understanding of the achievement trajectory of our learners. We have retold the predictable story of advantage begetting advantage at one end of the distribution and compounding disadvantage at the other end. But schools have the capacity to positively change educational outcomes. In this report (using descriptive, inferential and multivariate analyses) we have teased out factors within schools that could promote improved mathematics and science achievement.

MATHEMATICS AND SCIENCE ACHIEVEMENTS, ACHIEVEMENT TRENDS AND GAPS

In TIMSS 2019, South African Grade 9 learners achieved an average of 389 (SE 2.3) on the mathematics assessment and 370 (SE 3.1) on the science assessment. This amounts to an increase of one standard deviation (104 TIMSS points for mathematics and 102 points for science) between the 2003 and 2019 cycles.

In 2019, 41 percent of mathematics learners and 36 percent of science learners had acquired the basic subject knowledge and skills. This amounts to a fourfold increase for mathematics (from 11 percent to 41 percent) and a threefold increase for science (from 13 percent to 36 percent) from the TIMSS 2003 to 2019 cycles. The South African Gross Enrolment Rate for the secondary school phase increased from 83 percent in 2003 to 101 percent in 2018. Despite the expansion of the education system, and the challenges associated with accommodating and effectively teaching more learners, achievement still improved.





South African achievement continues to be unequal and socially graded. Achievement gaps, though decreasing, continue to be linked to socioeconomic backgrounds, gender, the spatial location of the school, proficiency in the language of the test, the extent of overage learners, attending fee-paying versus no-fee schools, and the province where the learner lives and attends school.

This confirms the well-known narrative that advantage begets advantage and home disadvantage continues to impede learning outcomes at school.

> The distributional achievement inequality measured by the difference in achievement scores between the 5th and the 95th percentile decreased from the 2003 to the 2019 cycles: by 68 points for mathematics, and 64 points for science.

THE MATHEMATICS AND SCIENCE CURRICULUM AND ACHIEVEMENT

TIMSS is not a simple assessment, with two-thirds of the assessment items requiring learners to use higher cognitive skills of application and reasoning. The South African Grade 9 Curriculum and Assessment Policy Statements (CAPS) has a higher focus on the skills of knowing and solving routine problems, and there is limited emphasis on the skills of applying and reasoning.

Three-quarters of the TIMSS mathematics and science content was taught in the South African curriculum before learners took the assessment. When compared to the average national mathematics and science scores, learners performed significantly better in the algebra and physics content areas, and experienced more difficulty in the content areas of geometry, data and probability, biology and Earth sciences. Learners achieved significantly lower scale scores for mathematics and science knowledge items, whereas the scale scores were significantly higher for mathematics reasoning items and science applying items.

INDIVIDUAL CHARACTERISTICS AND ACHIEVEMENT

One in three learners were overage for Grade 9. Learners who were the correct age for the grade achieved significantly higher scores than those who were overage.

Just over one in four learners spoke the language of the test at home, which is used as a proxy for language proficiency. Learners who were more proficient in the language of the test achieved significantly higher mathematics and science achievement scores than those who were less proficient.

Girls significantly outscored boys in both mathematics and science achievement, but when there was an interaction between gender and age the relationship changed.

HOME AND ACHIEVEMENT

The socioeconomic conditions in which learners live and learn explained 24 percent of the achievement variance. According to the *Home Asset Scale*, South African households were categorised as 20 percent high socioeconomic status (SES), 25 percent medium SES and 55 percent low SES. There was a significant, positive association between the SES of the household and learners' mathematics and science achievement, thus confirming the enduring finding in the literature that the circumstance of one's birth continues to be a predictor of a learner's educational and life trajectory.

Only one in three learners' parents were able to assist them with homework regularly as they could understand the language of the homework and the content (proxy for parental education level). There was a significantly positive association between the extent that parents were able to assist learners with homework, and their mathematics and science achievement scores.

THE SCHOOL AND ACHIEVEMENT

> There is a continuity of home to school conditions where learners from lower income households with fewer assets enter schools with limited access to resources and poorer teaching and learning cultures, perpetuating existing social inequality.

There is a high achievement variation among schools. The poverty rank of the school (quintile) a learner attends explained 26 percent of the achievement variance. Learners in no-fee schools were almost exclusively Black African, and 99 percent of Indian and White learners and 70 percent of Coloured learners attended the better resourced and functioning fee-paying schools.

The majority of South African schools and learners reported a school climate that was unsafe, and had high levels of discipline problems, incidences of bullying and disorderly behaviour in classrooms. All three school climate factors (safe and orderly schools, school discipline, and learner bullying) were significantly associated with mathematics and science achievement.

CLASSROOMS AND ACHIEVEMENT

Resources matter for educational success. Learners achieved higher results in schools with better resources. Having their own textbook and workbook was significantly associated with higher mathematics and science achievement. Overall, 85 percent of mathematics learners and 54 percent of science learners had their own workbooks, and two-thirds of mathematics learners and half of the science learners had their own textbooks. The results provide clear evidence that learners with their own workbooks and textbooks achieved higher achievement scores than learners who either shared or did not have a textbook or workbook.

The number of learners in a class matters: 70 percent of TIMSS Grade 9 learners were taught in classes with more than 40 learners. Learners attending classes with less than 40 learners achieved significantly higher scores than those in classes with more than 40 learners.

The quality of instructional practices matters. Learners taught by educators rated as providing high instructional clarity achieved significantly higher on the mathematics and science assessments.

LEARNER ATTITUDES TO MATHEMATICS AND SCIENCE

An interesting finding from the study relates to non-cognitive influences, e.g. self-reflection of ability. Learner attitudes and experiences at school explained 16 percent of the achievement variation. Learners who had high confidence in their mathematical and scientific abilities achieved higher scores.

IMPLICATIONS AND RECOMMENDATIONS FROM THE TIMSS RESULTS

The South African state, society and labour market are all committed to ensuring that schools have better educational outcomes. Thus, we highlight five high-level recommendations to improve educational outcomes.

1. **Continue monitoring achievement:** Periodic assessment of educational achievement is important. TIMSS is the only 24-year achievement trend study that provides valuable information to monitor and evaluate the South African education system. South Africa must continue participation in international trend studies. We must continue participation in TIMSS 2023, especially at Grade 9 to maintain the trend achievement line.
2. **Well-functioning schools matter:** About 30 percent of schools (mostly fee-paying) are considered better functioning schools. The state should focus on whole school development with a key target being to increase the number of well-functioning schools. The focus should be on how to improve school climate by encouraging the emphasis on academic success and making schools safer places for learners and educators. Unsafe, disruptive classrooms, where bullying is frequent and discipline is a problem, disrupt the learning environment and hinder performance. School safety is a matter that needs to be tackled by the state, society, school and the home.
3. **Resource availability and how it is used matters.** In the short term, all learners must have their own mathematics and science workbook and textbook, especially in remote rural schools. Decreasing class sizes is also an important piece of the resourcing puzzle: learners should be taught in smaller classes measured by actual headcount rather than learner-educator ratios. The longer-term strategic interventions needed include increasing access to computers and Internet connectivity, and the availability of science laboratories.

4. We need to know more about **educators and their utilisation in schools**. We do not have definitive information about educators' qualifications, their subject specialisations, how they are utilised in schools and how classroom timetabling occurs. We need a national audit to have a better understanding of these matters and to identify the factors constraining educational outcomes.
5. Pay greater attention to the **non-cognitive dimensions** that are associated with achievement. Learners' self-reflection of their mathematics and science abilities (self-efficacy) was positively associated with achievement. In this bidirectional relationship, the honest appraisal by learners of their ability to learn mathematics and science should be the start of a conversation about the effort that learners need to put into the learning process, and the support they require, in order to improve their achievement.

IN CONCLUSION

The South African education system remains a fragile one, and it has been dealt a major blow by the coronavirus pandemic. It is predicted that the country will not reach the achievement targets set out in Medium Term Strategic Framework if we continue on the current trajectory.

TIMSS 2019 has provided an evaluation of the current South African education system, indicating that our learners are still experiencing multiple barriers to achievement. As is the case with nearly all research investigating the influences on learner achievement, there is no 'silver bullet' that will fix low performance, remediate years of social imbalance throughout the system, and penetrate the indelible association between one's circumstances at birth and economic and social outcomes; but these results, like those of previous TIMSS studies, highlight that there are many areas that can and must be improved.

SECTION A

FRAMING THE TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY IN SOUTH AFRICA

The Trends in International Mathematics and Science Study (TIMSS) is an assessment of the mathematics and science knowledge of fourth or fifth, and eighth or ninth grade learners around the world. TIMSS allows participating nations to compare their learners' educational achievement across borders as well as provide a series of trend measures, allowing countries to measure and monitor the health of their education systems over time. Demographic and contextual information collected from learners, educators, parents and schools provides a rich dataset to explain the observed achievement levels. TIMSS was first administered in 1995, and subsequently every four years.

Measuring and monitoring educational progress over time is a priority for the South African Government. This is done through participating in a number of national, regional and international achievement studies, one of which is TIMSS. TIMSS 1995 was the first time that South Africa participated in this international assessment study at Grade 8. The study was repeated at Grade 8 in 1999 and 2003. In 2003, South Africa also assessed learners at Grade 9. South Africa's low achievement scores raised uncertainties about the credibility of estimated scores. To obtain better score estimates, South Africa assessed learners at Grade 9 in 2011, 2015 and 2019.

Thirty-nine countries and seven benchmarking participants (i.e. states, counties, provinces or cities) participated in the TIMSS 2019 cycle. In addition to South Africa, the Western Cape and Gauteng provinces participated in TIMSS 2019 as 'benchmarking participants'.

In order to frame the reading of the results from TIMSS 2019 in this report, this chapter will focus on two main aspects: (i) TIMSS in the South African education landscape and (ii) Design and methodology of TIMSS 2019.

CHAPTER ONE

FRAMING THE TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY IN SOUTH AFRICA

South Africa participated in TIMSS at Grade 8 or 9 since 1995, and therefore has a 24-year achievement dataset which is valuable for monitoring changes in educational outcomes. What did we learn about mathematics and science achievement in South Africa from the previous TIMSS cycles? Our analysis from 1995 to 2015 showed that South African educational performance outcomes improved, although they are still low when compared with other participating countries, unequal and socially graded. Achievement gaps, though decreasing, continue to be linked to population groups, socioeconomic backgrounds and disparate school contexts. This confirms the well-known story that advantage begets advantage, and home disadvantages continue to schools. Thus, challenges for quality learning are compounded, resulting in differentiated outcomes for children from different strata of society (Reddy et al., 2016).

South Africa started with very low learning outcomes in 1995, with only one in ten learners demonstrating they had acquired the minimum mathematical and science knowledge and skills for that grade. TIMSS achievement results had improved by 2015, with South Africa showing the biggest improvement of the set of participating countries. Yet, while there have been education successes, the rate of improvement in learning outcomes has been slowing down and is lower than desired by both society and the economy. There are still too few learners who are achieving learning outcomes that will allow them to progress successfully through the schooling system, into post-school education and training qualifications, and to access higher job levels and incomes. The TIMSS 2019 results will extend our understanding of the education achievement trajectory for South Africa.

1.1. TIMSS IN THE SOUTH AFRICAN EDUCATION LANDSCAPE

Numerical, mathematical and scientific skills are globally recognised as key competences for the development of an individual, a modern society and an increasingly knowledge and technology-based economy. Mathematics provides an effective way of building mental discipline and encouraging logical reasoning. In our complex and fast-changing world, scientific knowledge allows us to develop and understand new technologies, solve practical problems, and make informed decisions. Foundational reading, numerical and scientific skills are critical for any future learning. The acquisition of mathematical and scientific knowledge is hierarchical in nature, being dependent on foundational knowledge and skills, and therefore learning cannot be leap-frogged.

Mathematics and science achievement at school is a signal of the future ability of learners to participate in society as engaged citizens, and to continue studying technical subjects in post-school education and training. Learners with sound mathematical and science skills can be expected to participate in higher level cognitive reasoning and problem-solving tasks and are considered to possess abilities that make them more trainable in a number of jobs, giving them higher labour market mobility and freedom. South Africa has embarked on an inclusive economic development pathway dependent on science, technology and innovation for which school mathematics and science competencies are necessary (Republic of South Africa (RSA), 2012b).

Performance in school mathematics and science is one of the key indicators to describe and measure the health of our educational system. Mathematics and science under-performance continues to contribute to social inequalities in terms of access and income. Changes in school mathematics and science performance will provide a measure of the extent of transformation in schools, and in the wider society since the inception of the democratic state.

Education and development

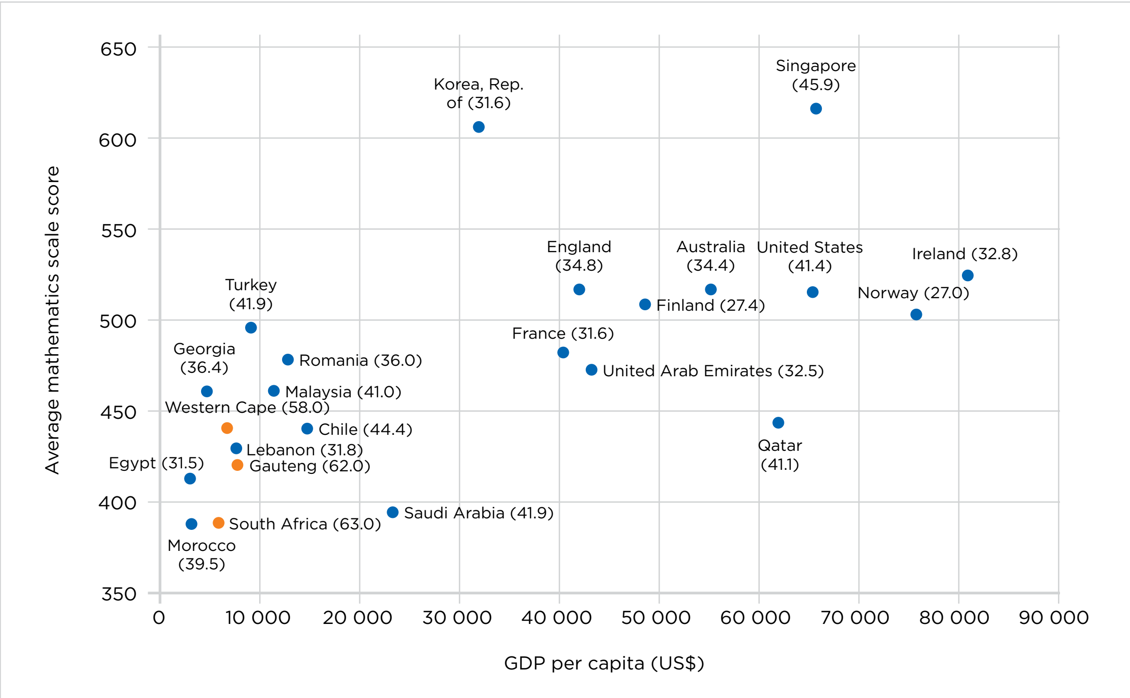
South Africa continues to face the challenges of high levels of poverty, inequality and unemployment. Social and economic inequalities in South Africa have been persistent, primarily because of their deep roots in the country's legacy of racial exclusion under the regime of segregation; and these inequalities have been compounded by contemporary challenges. The Gini coefficient, which measures income inequality, is higher for South Africa than all other countries for which comparable data are available (The World Bank, 2018). The stubbornly high level of inequality mirrors South Africa's polarised society, with a small elite, a relatively small middle class, and a large proportion of poor people. In 2015, the economic categorisation of the population was 49 percent chronic poor, 13 percent transient poor, 14 percent vulnerable, 20 percent middle class and four percent elite (The World Bank, 2018).

Low educational attainment, characterised by poor learning conditions, experiences and outcomes, has been a contributory factor in the persistent unequal labour market outcomes observed over the last decade. The Organisation for Economic Co-operation and Development (OECD) analysed global and labour force inequalities and identified four driving forces of inequality within emerging countries: spatial divides, *gaps in education*, barriers to employment, and career advancement for women (OECD, 2011).

Education is key to development and is central to whether social and economic development is sustainable. While education is key to development, it is also dependent on the state of development of a country. Thus, education quality is both a determinant and an outcome of the stage of development within a country – creating challenges for systems with low education levels and low levels of economic development. To illustrate the relationship between economic development and educational achievement, Figure 1 plots the average mathematics score of Grade 9 learners and the corresponding Gross Domestic Product (GDP) for a few of the participating TIMSS countries.

South Africa, with Morocco, attained the lowest mathematics scores in TIMSS 2019. However, the South African GDP per capita is higher than that of Egypt, Jordan and Georgia, all of which achieved higher average mathematics scores. We therefore need to look further than GDP to understand achievement. Cross-country studies undertaken by the OECD have found that the highest performing education systems are those that combine quality with equity (OECD 2016). Therefore, we included the Gross National Income (GNI) Index of Income Inequality to illustrate the level of income inequality within a country (provided in brackets after each country name). South Africa has the highest GNI Index of Income Inequality, with most other TIMSS countries having a GNI almost half that of South Africa. The level of income inequality within South Africa seems to be a contributing factor to its lower average achievement scores.

Figure 1: Average TIMSS 2019 mathematics scores and Gross Domestic Product (Index of Income Inequality)



Note: Country data were retrieved from the World Bank DataBank[1] in September 2021, and values from 2019 were used. Provincial data were retrieved from Statistics South Africa[2], and 2017 values were used.

1 https://databank.worldbank.org/home.aspx
2 http://www.statssa.gov.za/?p=12056

Prioritising education in South Africa

The apartheid state used education, and in particular mathematics education, for the under-development of the Black[3] and especially African population. The democratic state has a responsibility to introduce interventions and active strategies to equalise the injustices of the past. Since 1994, the democratic government has emphasised the centrality of education, especially reading, numeracy and mathematics, and science, for development. Section 29 of the South African Constitution outlines the right to a (i) basic education, including adult basic education; and (ii) to further education, which the state, through reasonable measures, must make progressively available and accessible (RSA, 1996a). These rights impose a positive obligation on the state to promote and provide education by putting in place and maintaining an education system that is responsive to the needs of the country.

The National Development Plan (NDP) 2030 is the guiding document for development in South Africa. Its action plan focuses on responding to the triple challenges of poverty, inequality and unemployment. The NDP makes it clear that the education system will play a greater role in building an inclusive society, providing equal opportunities, and helping all South Africans to realise their full potential, in particular those previously disadvantaged by apartheid policies, namely Black people, women and people with disabilities (RSA, 2012b, p. 296).

The NDP informs the Medium-Term Strategic Framework (MTSF) for the 2019–2024 period (Department of Performance Monitoring and Evaluation (DPME), 2020). One of the aims of the MTSF is to address the challenges of unemployment, inequality and poverty through building and strengthening the capabilities of South Africans. Accordingly, the first education priority in the MTSF remains having capable and committed teachers in place. The MTSF acknowledges that although progress has been made, significant gaps remain with regard to (i) access to learner support materials; (ii) school facilities and infrastructure, and (iii) access to modern media and connectivity (DPME, 2020).

The Strategic Plan of the Department of Basic Education (DBE) (2019–2024) (DBE, 2020a) articulates 27 goals for education. Goals 1 to 13 specify the outputs the DBE wants to achieve in relation to learning: these relate to improved competencies in languages, mathematics/numeracy, and physical sciences. These in turn are expected to lead to higher levels of grade promotion. Goals 14 to 27 deal with what the DBE must do in order to achieve the stated outputs.

Focusing on achievement and achievement gaps

In an ideal world, achievement gaps should only reflect differences in ability and effort. But in most educational systems, the achievement gaps that exist are associated with a number of background factors. There is extensive South African literature documenting the low and unequal educational outcomes in the country (Reddy, 2005; Fleisch, 2008; Reddy, Van der Berg, Janse Van Rensberg & Taylor, 2012). Research on factors that shape individual educational outcomes has highlighted how race, gender, home background and socioeconomic status (SES), the type of educational institution attended, and geographic location continue to influence the embeddedness of inequality from basic education through to the labour market.

Both scholarly and public debates on the topic of inequality generally distinguish between inequality of outcomes and inequality of opportunities (Ramos & Van de Gaer, 2020; Roemer & Trannoy, 2016). While inequality of outcomes is concerned with disparities in material wealth, income or expenditure; inequality of opportunities attributes differences to circumstances beyond individual control, such as gender, ethnicity, place of birth, or family background. The inequality of opportunities framework, in understanding educational inequalities, recognises those parts of inequality caused by circumstances outside individuals' control, which merit compensatory intervention; and parts of inequality that are generated by individual choices, talent and effort which are considered fair and should not necessarily be circumscribed (Ferreira & Gignoux, 2011; Roemer & Trannoy, 2016).

In both developed and emerging economies, factors of race and gender, as well as parental wealth and educational attainment, are the main determinants of children's educational success (The World Bank, 2018).

3 The term Black is used to describe the population group that were not White, i.e. African, Coloured and Indian groups.

Observations show that children from poor families are less likely to start, progress or complete schooling successfully, and consequently have lower employment outcomes (Duncan et al., 2007). Disparities in cognitive and non-cognitive, literacy and numeracy skills are already evident when children enter school, and these skills are predictive of subsequent academic performance (García & Weiss, 2017).

In order to appreciate the effect of inequalities on the lives of individuals, we use the 2006 World Development Report's description of the living conditions and educational trajectories for two South African children born on the same day in 2000:

> "Nthabiseng is black, born to a poor family in a rural area in the Eastern Cape province, about 700 kilometers from Cape Town. Her mother had no formal schooling. Pieter is white, born to a wealthy family in Cape Town. His mother completed a college education at the nearby prestigious Stellenbosch University. On the day of their birth, Nthabiseng and Pieter could hardly be held responsible for their family circumstances: their race, their parent's income and education, their urban or rural location, or indeed their sex. Yet statistics suggest that those predetermined background variables will make a major difference for the lives they lead. Nthabiseng is likely to be considerably poorer than Pieter throughout her life" (The World Bank, 2006, p. 1).

Writing the story for Nthabiseng and Pieter in 2020, the conditions of their birth continue to determine their educational and labour market trajectories. Pieter would continue to complete his school and tertiary education and have better opportunities to rise to managerial positions in the private sector labour market. Nthabiseng would continue to look for opportunities for a good school education, and funding for tertiary education, and would still have difficulty accessing the private sector labour market (Reddy & Mncwango, 2021).

The framework informing the South African TIMSS 2019 analysis is educational inequalities and in particular, achievement and achievement gaps. We acknowledge the role of home SES but interrogate the data to identify ways that schools and classrooms can become equalising influences. The TIMSS 2019 South African report **Building Achievement and Bridging Achievement Gaps** continues the journey to monitor our educational achievement outcomes and identify factors that could contribute to improved achievement scores.

It is in this context and with these policy questions in mind that South Africa participates in TIMSS. In the next section we discuss the TIMSS design and methodology and how we implemented the study in South Africa.

1.2. TIMSS DESIGN AND METHODOLOGY

What is TIMSS?

The Trends in International Mathematics and Science Study (TIMSS) was developed by the International Association for the Evaluation of Educational Achievement (IEA) and is managed by the TIMSS and PIRLS International Study Center at Boston College in the United States. The main goal of TIMSS is to assist countries to monitor and evaluate their mathematics and science teaching and learning, as well as their achievement outcomes, over time and across different grades.

For full details about the history of IEA and the studies they conduct see the IEA website[4].

The TIMSS 2019 assessment was the seventh cycle of TIMSS. The cycles have been conducted every four years since 1995. To inform educational policy in the participating countries, TIMSS also collects extensive background information on the home and school contexts in which teaching and learning take place. This background information is collected through a series of questionnaires for learners, parents, mathematics and science educators, school principals and curriculum specialists.

Thirty-nine countries, including South Africa, participated in the TIMSS 2019 cycle for senior phase learners, or Grades 8 and 9. In addition to the 39 countries, there were seven benchmarking participants, including the Gauteng and Western Cape provinces from South Africa.

In addition to the IEA and the TIMSS and PIRLS International Study Centre, a number of other agencies are involved in different aspects of the study. TIMSS sampling procedures were overseen by Statistics Canada and

4 https://www.iea.nl/studies

the Sampling Unit at IEA Hamburg. The IEA Secretariat and the TIMSS and PIRLS International Study Centre oversaw the instrument translation and verification processes, as well as the quality assurance programme; and IEA Hamburg was responsible for oversight of the data collection, data processing and data analysis.

In this section we will provide an overview of the TIMSS Study Design and Methodology. We provide the operational details and procedures in Annexure 1.

TIMSS in South Africa

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

For better insights into education and achievement in primary schools, South Africa conducted the TIMSS 2015 Numeracy assessment at the fifth grade. TIMSS 2019, at the fifth grade, included 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 more precise provincial achievement estimates. The sample size in these two provinces, for TIMSS 2019, increased to 150 schools, while sample sizes in the other provinces remained at 30 schools each. The TIMSS 2019 International Results in Mathematics and Science[5], in addition to reporting information for South Africa, also reports on Western Cape and Gauteng provinces as self-standing entities called ‘benchmarking participants’.

The TIMSS 1995, 1999 and 2003 cycles were funded by the HSRC. In 2011, the DBE adopted the TIMSS outcomes as one of the key indicators of educational performance in the country, and this study was included within the DBE’s strategic plan. For a history of TIMSS in South Africa please see the publication by Reddy and Hannan (2021)[6].

Why does South Africa participate 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 provided data to monitor the trend in mathematics and science achievement, and TIMSS 2019 offered the opportunity for another point to monitor and explain, our educational achievement. The key questions informing the analysis of the South African TIMSS 2019 data in this report are:

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

TIMSS conceptual framework

TIMSS uses the curriculum as the key organising concept in evaluating how education opportunities are provided to learners, and the factors that influence how learners use these opportunities. There are three key aspects to the TIMSS Curriculum Model: the intended curriculum, the implemented curriculum, and the attained curriculum (see Figure 2).

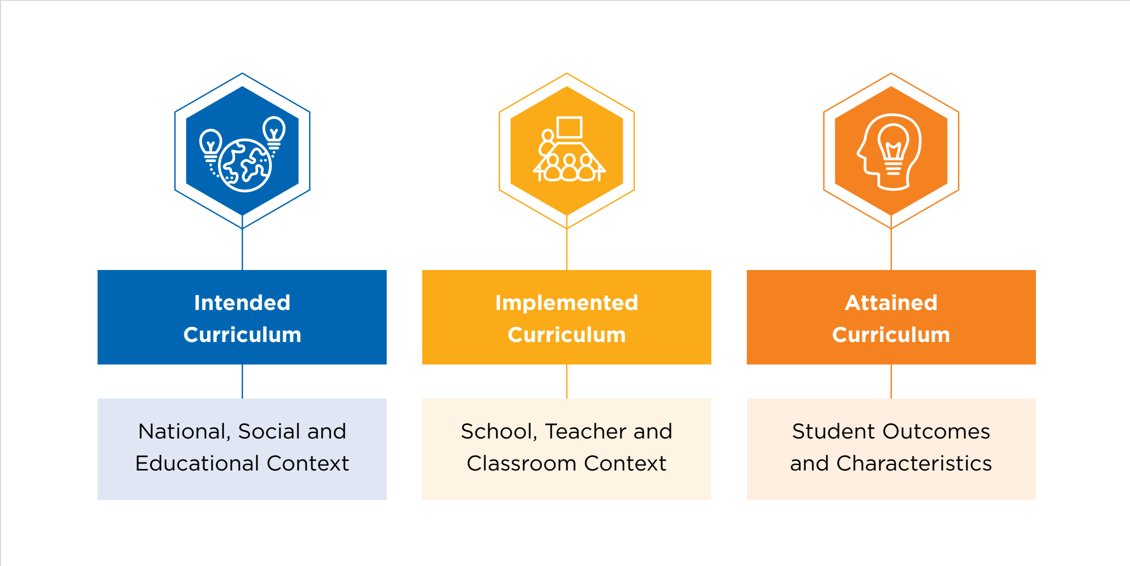
The *intended* curriculum refers to what mathematics and science content learners are expected to learn as defined by a country’s curricula policies and publications.

The *implemented* curriculum refers to how the educational system is structured to facilitate this learning; what is actually taught in classrooms; the characteristics of the individuals teaching it and how it is taught.

The *attained* curriculum refers to what learners have learned, as demonstrated by their attitudes and achievement.

5 https://timss2019.org/reports/
6 https://www.timss-sa.org/publication/timss-in-south-africa-making-global-research-locally-meaningful

Figure 2: TIMSS Curriculum Model



The TIMSS Assessment Framework

The TIMSS 2019 Assessment Framework[7] (Mullis & Martin et al, 2017) provides the conceptual underpinning for the TIMSS 2019 assessment instruments. As TIMSS assesses both mathematics and science, the two subjects are treated separately within the assessment framework. Each subject is organised around two dimensions of domains – a content domain and a cognitive domain. The *content domain* specifies the subject matter to be assessed, while the *cognitive domain* specifies the thinking processes to be assessed. Further details about the content and cognitive domains are found in Chapter Four of this report.

What did participants do?

Learners who participated in TIMSS 2019 completed a paper-based assessment booklet containing an even distribution of both mathematics and science items. These booklets were designed to be administered in two sessions, separated by a short break. Each session was 45 minutes in duration. In addition to completing the achievement booklet, each learner completed a background questionnaire. Grade 9 learners took part in the assessment in August 2019.

The achievement booklets

TIMSS aims at providing a comprehensive picture of mathematics and science achievement. The complete TIMSS assessment thus comprises a large pool of mathematics and science items. To limit the burden on any one learner, TIMSS uses a matrix sampling approach whereby the entire assessment pool is packaged into clusters. These clusters are rotated through 14 achievement booklets, such that each cluster is included in more than two booklets. Each booklet contains two item blocks per subject (mathematics and science) and comprises both multiple choice and constructed items. There are a total of 14 booklets, but each learner completes only one of these booklets. Item blocks provide a mechanism through which to link learners' responses from the various booklets.

The TIMSS achievement booklets contain both trend and non-trend items. The trend items form an anchor that allows for estimating achievement over time. The non-trend items are new items generated for each cycle. For more details on the assessment frameworks and matrix design refer to the TIMSS 2019 Assessment Frameworks[8].

7 https://timssandpirls.bc.edu/timss2019/frameworks/
8 https://timssandpirls.bc.edu/timss2019/frameworks/

The contextual questionnaires

To obtain greater insight and identify possible explanations for achievement scores, TIMSS includes a set of contextual questionnaires. These contextual, or background, questionnaires are nationally adapted by each country. Adaptations includes both language editing, e.g. changes to spelling; as well as the inclusion of context-relevant questions, e.g. the language spoken at home by the learner in multilingual nations. Four background questionnaires are administered:

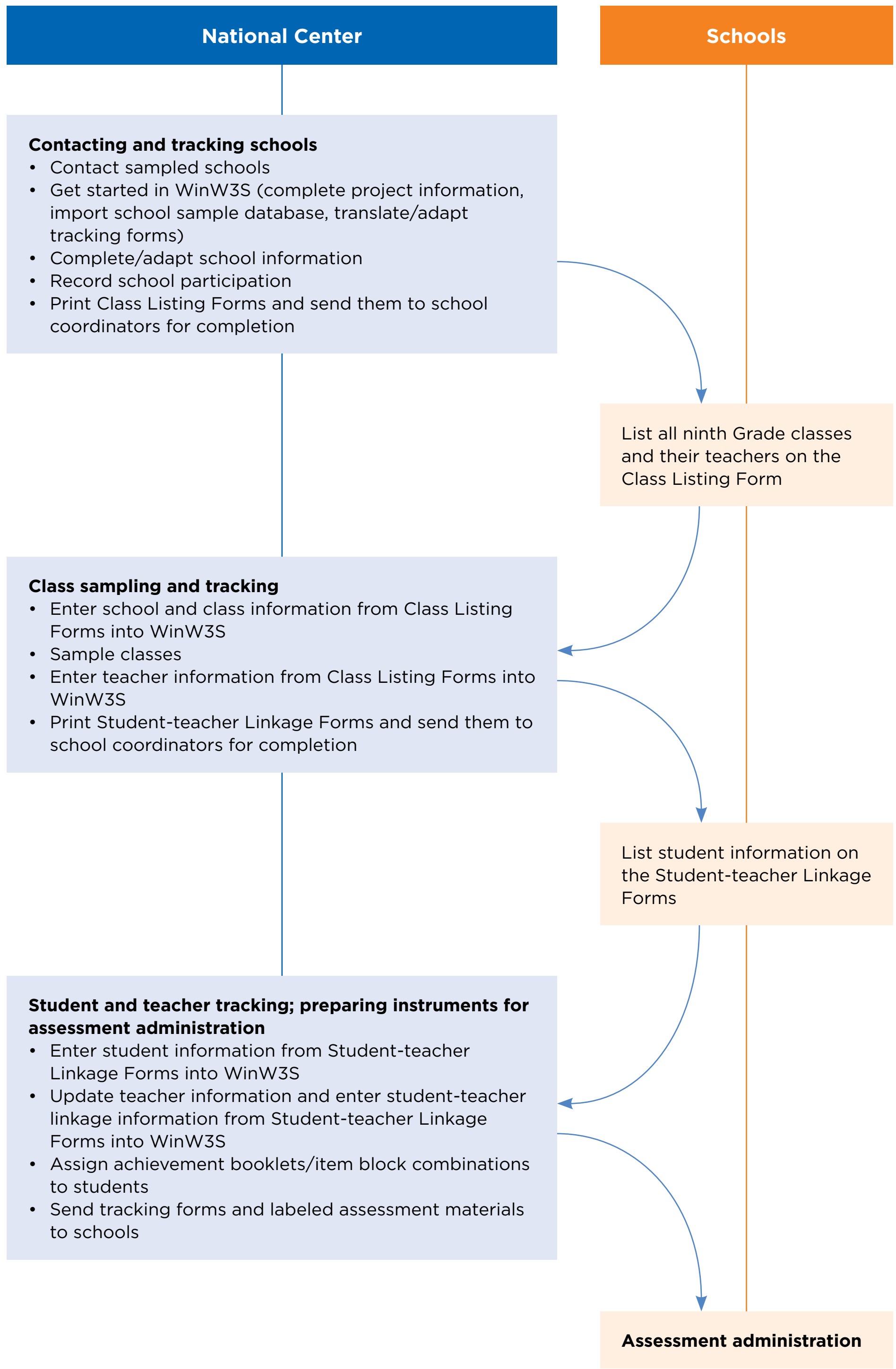
- The **Learner Questionnaire** asks about aspects of the learners' home and school lives, their home environment, their school climate for learning, and their perceptions and attitudes towards mathematics and science.
- The **Educator Questionnaire** is completed by both the mathematics and science educators of the participating learners. The questionnaire gathers information on educator characteristics, pedagogical practices, and the classroom context for teaching and learning.
- The **School Questionnaire** is completed by the principal in each of the sampled schools. It asks about school characteristics such as instructional time, available resources and technology, and school climate, as well as parental involvement.
- The **Curriculum Questionnaire** is completed by the National Research Coordinator, who gathers information pertaining to the curriculum followed by South African public schools. Information from the Curriculum Questionnaire is largely reported in the TIMSS 2019 Encyclopedia[9].

TIMSS pre-administration and administration

Each participating country must complete a substantial amount of preparatory work prior to the administration of the assessment. This preparation must be in line with the guidelines provided by the international TIMSS team. All these procedures are discussed in detail in the TIMSS 2019 survey operations manuals (Units 1-7) within the TIMSS 2019 Methods and Procedures Manual[10]. Figure 3 provides a map for the sampling procedures and logistical preparation to administer TIMSS in classrooms (details provided in Annexure 1).

9 https://timssandpirls.bc.edu/timss2019/encyclopedia/
10 https://timssandpirls.bc.edu/timss2019/methods/index.html

Figure 3: TIMSS sampling procedures and preparations for the assessment administration



Adapted from reference: Martin, von Davier & Mullis (2020).

Selecting schools and learners

TIMSS in South Africa drew a representative sample of schools offering Grade 9 classes. TIMSS 2019 followed the sampling procedures described in the TIMSS 2019 Methods and Procedures Manual[11]. In the two-stage stratified cluster sampling design, schools were randomly selected at the first stage and an intact Grade 9 class was selected at the second stage.

In most countries or benchmarking participants, 150 schools and one classroom in each school were selected, resulting in about 4 500 participating learners. For the first time, Gauteng and Western Cape provinces were included as benchmarking participants, and each drew a boosted sample. South Africa reports the TIMSS achievements at both the national and provincial level. Hence, the Grade 9 sample included 150 schools from Gauteng, 150 schools from Western Cape, and at least 30 schools from each of the other seven South African provinces. The sample was weighted so that each province contributed their appropriate share to estimate the national score.

The stages of the sample selection were the following:

First stage: South Africa provided Statistics Canada with the sampling frame (DBE's master list of schools) to draw the South African sample. The sample was explicitly stratified by province and type of school (public and independent schools), and implicitly stratified by school quintile (refer to Reader's Guide). Schools in the sampling frame were those that offered Grade 9 classes and had no missing information on the stratification variables. From this sampling frame, a representative sample of 150 schools for Gauteng and Western Cape provinces, and around 30 schools for each of the other seven provinces were drawn. In addition to the sample of participating schools, a first and second replacement school were selected to be used should a school have refused to participate.

Second stage: Schools selected in the first stage then submitted a list of all Grade 9 classes in the school. From each of these, an intact class was randomly selected using sampling software, WinW3S, provided by the IEA. Generally, one class per school was randomly selected. However, in schools where class sizes were very small, more than one class was selected. In total, 524 schools were selected as the TIMSS 2019 sample.

Following sampling, WinW3S generated learner and educator tracking forms and labels that assigned a unique code to each individual taking part in the assessment. This code was later used to link all assessment instruments related to that individual, be it a principal, educator, or learner. The TIMSS 2019 realised sample is shown in Table 1.

Table 1: South African designed and achieved school and learner sample

Provinces	Sampled schools	Participating schools (N)	Participating learners (N)	Estimated number of learners	Proportion of the learner population
Eastern Cape	32	30	1 454	117 177	13
Free State	32	31	1 217	45 690	5
Gauteng	150	150	5 633	169 894	19
KwaZulu-Natal	35	35	1 631	198 438	23
Limpopo	33	33	1 666	120 182	14
Mpumalanga	30	30	1 427	67 263	8
Northern Cape	30	30	1 118	18 318	2
North West	32	32	1 332	61 965	7
Western Cape	150	149	5 351	77 600	9
South Africa	**524**	**520**	**20 829**	**876 527**	**100**

11 https://timssandpirls.bc.edu/timss2019/methods/index.html

Reporting TIMSS achievement scores

As noted earlier, TIMSS 2019 employed a matrix sampling approach to create learner achievement booklets, where learners completed only a sample of the total TIMSS assessment: approximately 70 items, across mathematics and science. Due to this, Item Response Theory (IRT) scaling methods were used to generate five plausible values to estimate the competency levels of learners, i.e. indicators of achievement. IRT estimates or scale scores are contingent on learner ability (correct responses) and item parameters like item difficulty, discrimination and guessing (in the case of items with multiple options).

Using complex statistical methods and demographic background variables, several achievement scores were imputed for each learner. This design solicits relatively few responses from each sampled learner, while maintaining a wide range of content representation when responses are aggregated across all learners. With this approach, however, the advantage of estimating population parameters is offset by the inability to make precise statements about individuals. Thus, TIMSS is only able to report findings for particular groups, not for individuals.

The TIMSS 2019 achievement results are summarised and reported on a scale that ranges from 0 to 1 000, with a centrepoint of 500. For ease of reading, decimals for achievement scores and percentage of learners were rounded off to whole numbers. Some values in figures and tables may therefore not add exactly to the totals. Standard errors were rounded to one decimal place.

In this report, we look at national achievement trends, for Grade 9, from 2003 to 2019. We also report on provincial and school fee-status trends from 2011 to 2019, as we have more reliable provincial sample sizes and the administrative data to be able to categorise the fee status of schools.

Structure of the report

A preliminary report on the 2019 assessment – titled *TIMSS 2019: Highlights of South African Grade 9 Results in Mathematics and Science* – was released in December 2020. The present report expands on the results presented in that Highlights Report.

Chapter 1 frames the Trends in International Mathematics and Science Study in South Africa. We outline key policy elements of the South African Education Landscape and the TIMSS Design and Methodology.

Chapter 2 and 3 reproduce, with additional detail, the results presented in *TIMSS 2019: Highlights of South African Grade 9 Results in Mathematics and Science*. These chapters describe the South African achievement for mathematics and science.

Chapter 4 focuses on the analyses of the mathematics and science curriculum, largely in relation to the content and cognitive domains.

Chapters 5 and 6 present the results from the contextual questionnaires and report on learners and their home environment, and learner attitudes towards mathematics and science respectively.

Chapters 7 and 8 use data from the Learner, School and Educator Questionnaires to report on schools and classrooms respectively.

Chapter 9 reports the results from a multivariate analysis which identified factors that were associated with learners' mathematics achievement.

Chapter 10 concludes with the key findings and implications for South Africa from TIMSS 2019.

SECTION B
ACHIEVEMENT AND ACHIEVEMENT GAPS

Thirty-nine countries and seven regional entities, called benchmarking participants, participated in the TIMSS 2019 Grade 9 assessment. Three countries from the African continent: Egypt, Morocco and South Africa participated, with South Africa as the only country from the sub-Saharan African region. Most countries participated at the eighth-grade level, whereas Norway and South Africa, as well as the Gauteng and Western Cape provinces, participated at the ninth-grade level. More than half of the participating countries administered the computerised version of TIMSS (eTIMSS) and almost half administered a paper version. The paper version used in previous TIMSS cycles was administered in South Africa.

TIMSS describes performance in two ways: The first is through the original achievement scale score, while the second is by characterising learners as having reached international achievement benchmarks. This section reports South African learners' achievement and identifies achievement gaps in mathematics (Chapter 2) and science (Chapter 3).

Drawing from the TIMSS 2019 International Results in Mathematics and Science (Mullis et al., 2020), each chapter first summarises the average scale scores for each of the participating countries, including South Africa. We then discuss South African Grade 9 learners' performance in relation to the international achievement benchmarks. We end this discussion by presenting the trend in achievement from the 2003 to 2019 cycles.

The second part of the chapter is informed by the HSRC's analyses in describing scale scores by locally relevant variables viz. province and the socioeconomic status (SES) of schools. For each of these analyses we will also report the changes from the 2011 cycle to the most recent 2019 cycle.

CHAPTER TWO

MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

As the world becomes more 'quantified', learners need to be well grounded in mathematical and technological thinking to manage successfully in school and society. We use mathematics everywhere: from everyday tasks such as counting and shopping, to more detailed mathematical problems such as interpreting data. Mathematics helps us to understand the world and provides an effective way of building mental discipline. Mathematics encourages logical reasoning, critical thinking, creative thinking, abstract or spatial thinking, problem-solving ability, and even effective communication skills. Analytical and reasoning skills are essential because they help us to solve problems and look for solutions.

2.1. MATHEMATICS ACHIEVEMENT

Mathematics achievement in an international context

South Africa, with Gauteng and Western Cape provinces as benchmarking participants, participated in TIMSS 2019. Figure 4 presents the average mathematics scale score with standard errors (SE) for countries that participated in the eighth and ninth grade assessments, together with the scale score distributions underlying the average scale scores. Then, we present the scale score range within each country by calculating the difference between the 5^{th} and 95^{th} percentiles.

The countries are arranged from highest to lowest average mathematics scale score. Five East Asian countries had the highest mathematics achievement, with Singapore, Chinese Taipei and Korea performing similarly. Japan and Hong Kong followed these countries. The five lowest performing countries were Oman, Kuwait, Saudi Arabia, South Africa and Morocco. The average scale scores for Saudi Arabia, South Africa and Morocco were not significantly different from each other.

The distributional inequality within countries (i.e. score difference between the 5^{th} and 95^{th} percentile) ranged from 224 points to 355 points. There were 26 countries, including South Africa, where the inequality distribution was less than 300 points and 13 countries with an inequality distribution greater than 300 points. Countries with the highest distributional inequality were Turkey, United Arab Emirates and Chinese Taipei; and those with the lowest inequality distribution were France, Italy and Morocco.

TIMSS achievement scale score

Each learner responds to only a subset of the TIMSS assessment items as the full item bank is too large. TIMSS therefore utilises Item Response Theory (IRT) in combination with population modelling to provide estimated achievement scores as though each learner had answered all items. The IRT or scale score is calculated by considering whether a learner answered the set of items administered correctly as well as the difficulty level of the item.

Learners complete their allocated assessment items and their scores on these items are combined with the demographic background of similar learners to calculate estimated scores for the full assessment. Five estimates, or plausible values, for each learner are drawn.

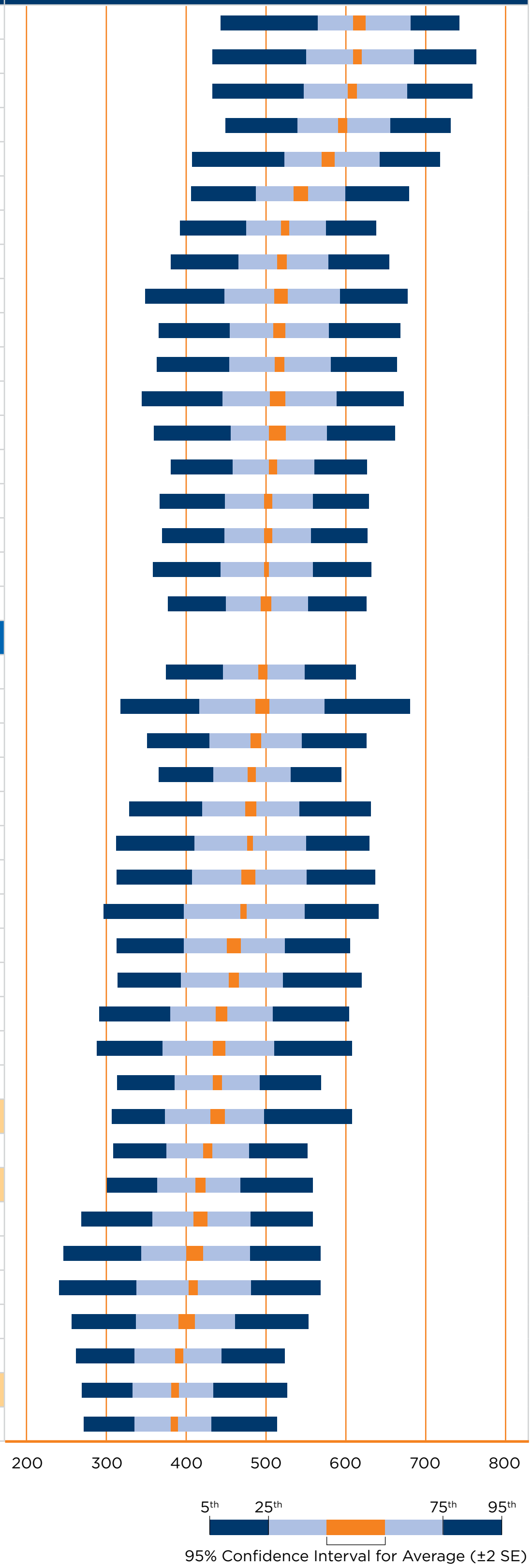
Plausible values indicate what the individual learner would have achieved for the entire assessment had they completed it.

The TIMSS achievement scale is summarised on a 0 to 1 000 scale, with a centrepoint of 500 and a standard deviation of 100. This report thus uses scale score to refer to learner achievement.

Figure 4: Average mathematics scale score and distribution, by country (TIMSS 2019)

Country	Average Scale Score (SE)		Score difference between 5th and 95th percentiles
Singapore	616	(4.0)	294
Chinese Taipei	612	(2.7)	324
Korea, Rep. of	607	(2.8)	320
Japan	594	(2.7)	276
Hong Kong, SAR	578	(4.1)	304
Russian Federation	543	(4.6)	267
Ireland	524	(2.6)	241
Lithuania	520	(2.9)	268
Israel	519	(4.3)	322
Australia	517	(3.8)	297
Hungary	517	(2.9)	295
United States	515	(4.8)	323
England	515	(5.3)	297
Finland	509	(2.6)	241
Norway (9)	503	(2.4)	256
Sweden	503	(2.5)	252
Cyprus	501	(1.6)	269
Portugal	500	(3.2)	243
TIMSS Scale Centerpoint	500		
Italy	497	(2.7)	233
Turkey	496	(4.3)	355
Kazakhstan	488	(3.3)	269
France	483	(2.5)	224
New Zealand	482	(3.4)	297
Bahrain	481	(1.7)	311
Romania	479	(4.3)	318
United Arab Emirates	473	(1.9)	337
Georgia	461	(4.3)	286
Malaysia	461	(3.2)	299
Iran, Islamic Rep. of	446	(3.7)	307
Qatar	443	(4.0)	313
Chile	441	(2.8)	250
Western Cape, RSA (9)	**441**	**(4.4)**	**295**
Lebanon	429	(2.9)	238
Gauteng, RSA (9)	**420**	**(3.0)**	**253**
Jordan	420	(4.3)	284
Egypt	413	(5.2)	315
Oman	411	(2.8)	321
Kuwait	403	(5.0)	290
Saudi Arabia	394	(2.5)	256
South Africa (9)	**389**	**(2.3)**	**252**
Morocco	388	(2.3)	237

Mathematics Achievement Distribution



Source: TIMSS 2019 international results report.

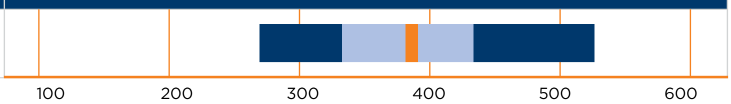
Reading a distribution or percentile graph

A percentile is a number between 1 and 99 indicating where a certain percentage of scores fall below that number. The TIMSS distribution graphs are drawn from the 5th to the 95th percentile with the confidence interval shown as well. The far left side of the graph marks the 5th percentile. This represents the point below which five percent of the assessed learners scored. The dark blue section of the bar covers the range between the 5th and 25th percentiles. The light blue section shows the range of scores between the 25th percentile and the lower limit of the confidence level for the average score. The right-hand side of the graph is read similarly, where the light blue section represents the scores between the upper limit of the confidence interval and the 75th percentile, and the dark blue section the scores between the 75th and 95th percentiles.

South African mathematics achievement and learners reaching international achievement benchmarks

TIMSS describes mathematics performance in two ways: scale scores and international achievement benchmarks. Figure 5 presents the average mathematics achievement, at the ninth grade for South Africa, together with the scale score distribution. The average mathematics scale score of South African learners was **389 (SE 2.3)**[12]. For South Africa, the distributional inequality (score difference between the 5th and 95th percentile), was 252 points, which was approximately mid-range in comparison to other participating countries.

Figure 5: Average South African mathematics achievement and scale score distribution (TIMSS 2019)

	Average Scale Score (SE)	Achievement Distribution
Mathematics	389 (2.3)	

Source: TIMSS 2019 South African Grade 9 dataset.

Further insight into learner achievement is derived from describing their performance in relation to the international benchmarks.

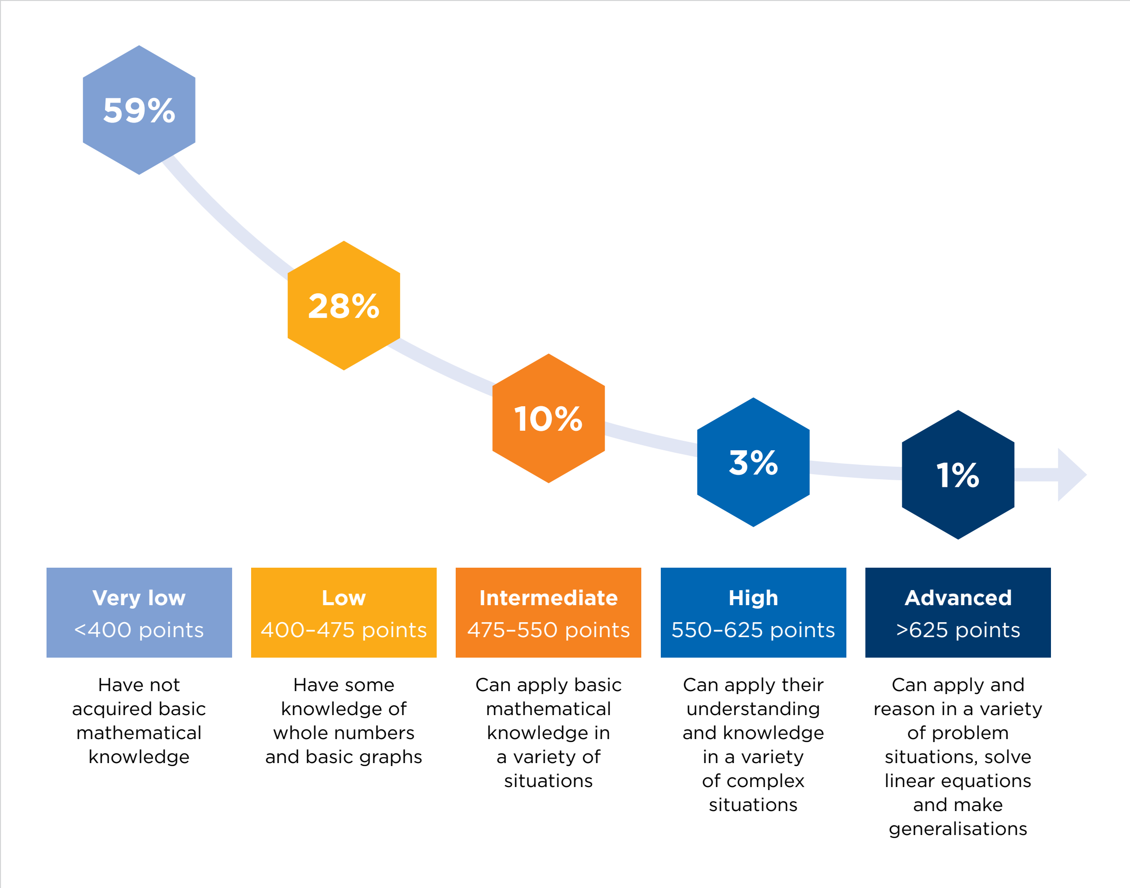
International achievement benchmarks are used to describe the abilities learners demonstrate (i.e. what learners know) at particular points on the achievement scale. TIMSS describes four points on the scale in terms of ability: Low (400 to 475 points); Intermediate (475 to 550 points); High (550 to 625 points); and Advanced (>625 points). We included the descriptor 'Very Low' for average scores less than 400 points.

Figure 6 provides the percentage of South African Grade 9 learners who reached each of the achievement benchmarks for mathematics. The figure also presents the scale score range associated with each benchmark and provides a brief description of the abilities that learners would demonstrate at each of these points.

12 The **standard error (SE)** tells us how accurate the mean of any given sample is likely to be compared to the true population mean. The average scale score is calculated from the achievement of the sampled learners and is an estimation of the average score for the population if all Grade 9 learners in the country were to have written the assessment.

The **confidence interval (CI)** is a range of values that you can be 95 percent confident contains the true mean of the population. The confidence interval is calculated as a range from -1.96 SE to +1.96 SE.

Figure 6: Percentage of learners reaching mathematics international achievement benchmarks (TIMSS 2019)



Source: TIMSS 2019 South African Grade 9 dataset.

Cumulatively, 41 percent of South African learners demonstrated that they had acquired basic mathematical knowledge, achieving 400 points or higher. In contrast, the majority (59%) of learners did not exhibit mastery of basic mathematical knowledge. The country still has a long way to go to improve mathematical knowledge. Learners reaching the higher benchmarks of achievement are assumed to be able to also do what is described in the lower achievement benchmarks.

It is, however, noteworthy that one percent of South African mathematics learners achieved at the advanced benchmark, attaining scores higher than 625 points. In subsequent analyses, we combine the *High* and *Advanced* International Benchmarks, and use the term "High International Benchmark" to describe all achievements above 550 points.

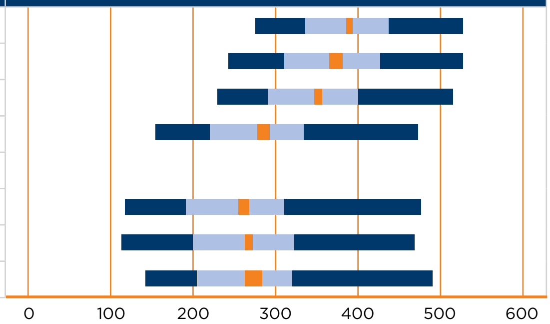
Trends in mathematics achievement from 1995 to 2019

TIMSS is the only South African trend measure dataset spanning 24 years of achievement. This section provides the trend analysis of average scale scores over the 1995 to 2019 period to measure national changes. Figure 7 presents the Grade 8 average mathematics scale scores for the TIMSS 1995, 1999 and 2003 cycles, and the Grade 9 average mathematics scale scores for the TIMSS 2003, 2011, 2015 and 2019 cycles.

Figure 7: Trends in average mathematics scale score and distribution from 1995 to 2019

	Average Scale Score (SE)		Score difference between 5th and 95th percentiles
Gr9 TIMSS 2019	389	(2.3)	252
Gr9 TIMSS 2015	372	(4.5)	286
Gr9 TIMSS 2011	352	(2.5)	287
Gr9 TIMSS 2003	285	(4.2)	320
Gr8 TIMSS 2003	264	(5.5)	376
Gr8 TIMSS 1999	275	(6.8)	372
Gr8 TIMSS 1995	276	(6.7)	352

Mathematics Achievement Distribution



Source: TIMSS South African Grade 8 and 9 datasets.

The South African Grade 8 average mathematics scale scores were not significantly different in the TIMSS 1995, 1999 and 2003 cycles (Reddy et al., 2012). In 2003, we assessed learners in both Grade 8 and Grade 9. On average, Grade 9 learners scored 21 points more than Grade 8 learners. This 2003 assessment of both Grade 8 and 9 learners provides the bridge for the 1995 to 2019 trend line.

Between TIMSS 2003 and 2011, the average Grade 9 mathematics achievement increased by 67 points. There was a further increase by 20 points between TIMSS 2011 and 2015 (Reddy et al., 2016). This clear upward trajectory was sustained as mathematics achievement increased between TIMSS 2015 and 2019 by a further 17 points. The achievement differences between each of the different cycles were statistically significant (refer to Reader's Guide).

Taking a broad perspective of this 24-year period, from 1995 to 2003 there was no significant change in the average mathematics achievement scores, but from TIMSS 2003 to 2019 there was an increase of 104 points. This is an impressive improvement, especially within the context where secondary gross enrolment rates increased from 81 percent in 1994 to 101 percent in 2018 (World Bank, 2020). In 1994, following apartheid education, the country started with very low mathematics performance and abilities. Twenty-five years into democratic rule, the country recorded a one standard deviation increase in mathematics achievement.

The trend measure also provides an opportunity to investigate the rate of improvement in mathematics achievement. The average annual rate of achievement improvement from 2003 to 2019 was six points. We collected the data in 2002, 2011, 2015 and 2019. Closer analysis reveals that the annual improvement rate was different for two eight-year periods. In the first period (2003 to 2011), the average achievement improvement rate was 7.4 points per year; and for the second period (2011 to 2019), the average achievement improvement rate was 4.6 points per year. The implication of the slowing down of the achievement improvement rate is that it would take the country longer to reach the achievement levels to which it aspires.

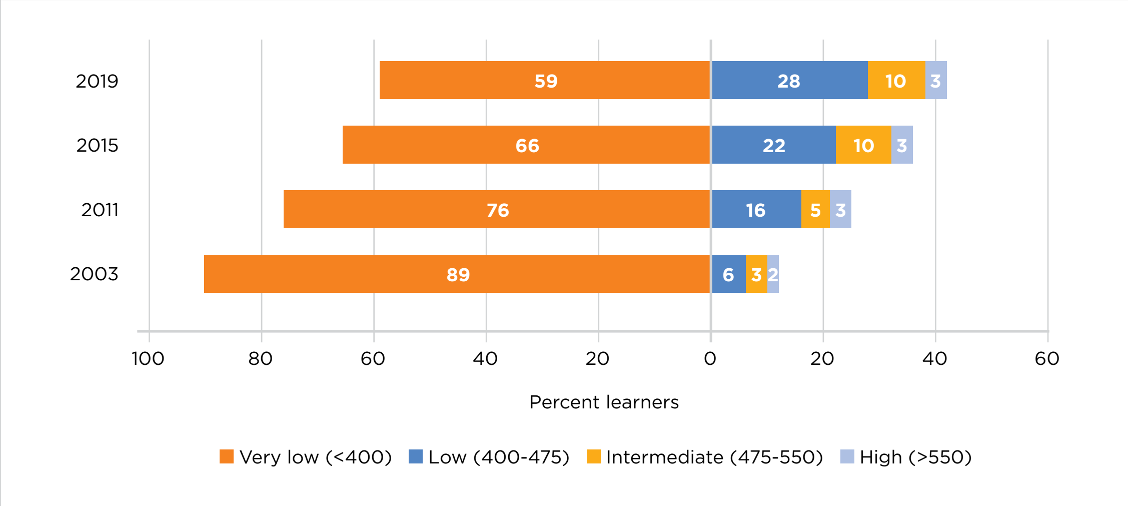
The achievement range (achievement difference between the 5th and 95th percentile) measures the extent of educational inequality in South Africa. Mathematics achievement inequality decreased by 68 points from 320 points in 2003 to 252 points in 2019, indicating a slight decrease in educational inequality. The best achievement gains continued to be at the lower end of the achievement distribution, meaning that those with the lowest achievement scores, generally from poorer households and attending poorer schools, have improved the most. However, it is concerning that, since 2011, there has been very little improvement at the top end of the distribution curve.

Trends in learners reaching the international achievement benchmarks from 2003 to 2019

In line with increases in the mathematics achievement from 2003 to 2019, the mathematical ability levels of learners also improved. From 2003, with each subsequent TIMSS cycle, the percentage of learners demonstrating mathematics abilities at the different benchmarks increased (Figure 8).

As illustrated in TIMSS 2003, South Africa started from a very low educational base, with only 11 percent of learners demonstrating that they had acquired basic mathematical skills and knowledge for their grade. By 2019, this increased almost fourfold, with 41 percent of mathematics learners demonstrating basic mathematical abilities.

Figure 8: Trends in percentage of learners reaching international achievement benchmarks from 2003 to 2019



Source: TIMSS South African Grade 9 datasets.

2.2. MATHEMATICS ACHIEVEMENT GAPS

South Africa is a large and diverse country. Thus, a single national achievement score does not tell the local stories. Rather, better insights are provided through a more nuanced achievement story reported by the locally relevant categories of (i) the province in which the school is located; and (ii) the socioeconomic status (SES) of the school. In this section we will report on results from TIMSS 2019, as well as trends between the 2011 and 2019 cycles.

Mathematics achievement by province

The National Education Policy Act of 1996 (RSA, 1996b) 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 policies and programmes in Grades R to 12. Provincial achievement estimates provide information to monitor the progress across the nine departments.

The TIMSS 2019 provincial mathematics achievement, with the standard error, and comparisons with other provinces are presented in Table 2.

The top three performing provinces for mathematics were the Western Cape with an average scale score of 441, Gauteng with 421, and Free State with 396. The scale scores for the six other provinces, Northern Cape, North West, KwaZulu-Natal, Mpumalanga, Eastern Cape and Limpopo, were lower than the national average score. Table 2 describes the achievement comparison between provinces, and highlights whether the difference was statistically higher, statistically lower, or where there was no statistically significant difference from the comparison province. The achievement scores of the top two provinces were significantly different from each other, as well as the other seven provinces.

The difference in mathematics achievement between the highest and lowest performing provinces was 77 points, quantifying the provincial achievement gap.

Table 2: Average provincial mathematics scale score and comparison between provinces (TIMSS 2019)

		Comparison province								
Province	Average Mathematics Scale Score	Western Cape	Gauteng	Free State	North West	KwaZulu-Natal	Northern Cape	Mpumalanga	Eastern Cape	Limpopo
Western Cape	441 (4.4)		▲	▲	▲	▲	▲	▲	▲	▲
Gauteng	421 (3.0)	▽		▲	▲	▲	▲	▲	▲	▲
Free State	396 (5.5)	▽	▽			▲	▲	▲	▲	▲
North West	383 (6.0)	▽	▽						▲	▲
KwaZulu-Natal	378 (5.4)	▽	▽	▽						
Northern Cape	377 (4.5)	▽	▽	▽						▲
Mpumalanga	375 (6.2)	▽	▽	▽						
Eastern Cape	366 (6.6)	▽	▽	▽	▽					
Limpopo	364 (5.5)	▽	▽	▽	▽		▽			

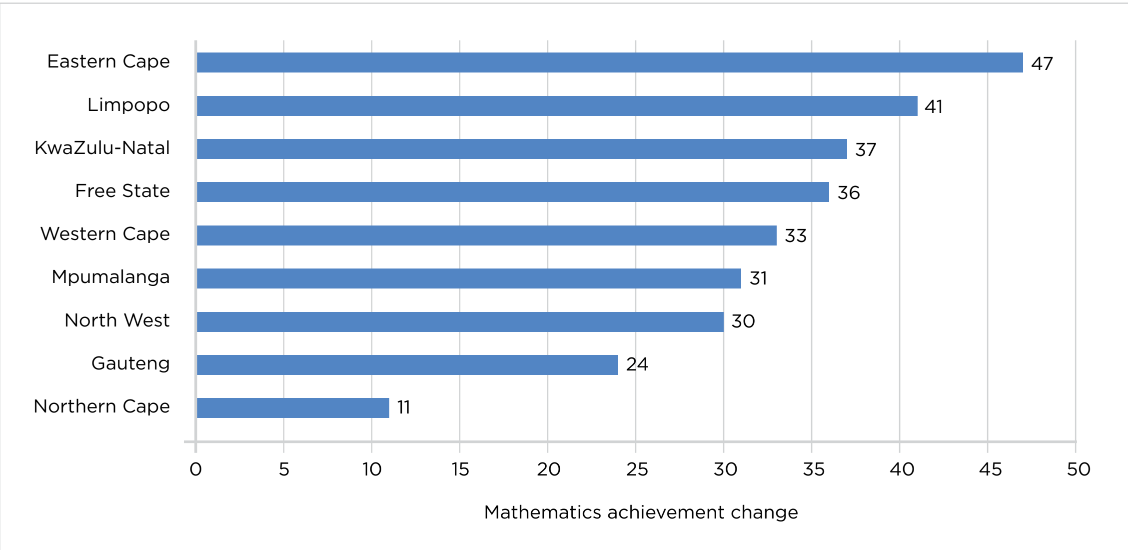
The symbols indicate whether the average achievement of the province was significantly higher (▲) than that of the comparison province, significantly lower (▽) than the comparison province, or that there was no statistically significant difference (blank blocks).

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Trends in mathematics achievement by province from 2011 to 2019

In line with the improvements of the national achievement over time, we expect improvements in average provincial mathematics achievement. We calculated the achievement difference for each of the provinces for the 2011 to 2019 period. Bars to the right of the '0' line in Figure 9 represent an increase in achievement scores from 2011 to 2019. The length of the bar reflects the amount by which the provincial achievement increased.

Figure 9: Change in average mathematics scale score, by province from 2011 to 2019



Source: Author's own calculations from TIMSS 2011 and 2019 South African Grade 9 datasets.

The highest achievement improvements over the 2011 to 2019 period were for the two lowest performing provinces: Eastern Cape (by 47 points) and Limpopo (by 41 points). Northern Cape had the lowest improvement in mathematics achievement (by 11 points). Our significance testing (t-test) showed that the achievement difference, at the 95 percent confidence level, for all provinces between 2011 and 2019 was significant, except for the Northern Cape[13].

The achievement gap across provinces also decreased over this period. In TIMSS 2011, the mathematics achievement gap between the highest and lowest achieving provinces was 89 points. The provincial achievement gap decreased to 77 points in the 2019 cycle.

Mathematics achievement by socioeconomic status of the school

South African schools vary considerably with regard to the area in which they are located, and their access to infrastructure and resources. The DBE calculated a poverty index for each public school according to the income levels of the community around the school, the unemployment rate and the level of education of the community. Public schools are categorised into five (unequal) groups, called quintiles, with Quintile 1 being the most under-resourced schools in the most economically disadvantaged communities, and Quintile 5 being the best resourced schools in more affluent communities (See Chapter 7 for further details).

Table 3 reports the average mathematics achievement for schools in each quintile category, as well as for independent schools, and the comparisons between them. The average achievement for learners in Quintile 1 and 2 schools was similar, with no significant differences being observed, while the average achievement score for learners in Quintile 3 schools was significantly higher than for Quintile 1 schools. The average scale scores of learners in Quintile 4 schools (407 points) were significantly higher than the average scale scores in Quintile 1, 2 and 3 schools, and significantly lower than Quintile 5 and independent schools. The average learner scores in Quintile 5 schools (464 points) were not statistically different from learners in independent schools (478 points).

Table 3: Average mathematics scale score, by school quintile rank and independent schools, and comparisons (TIMSS 2019)

		Comparison quintile					
Quintile Rank	Average Mathematics Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	478 (8.3)			▲	▲	▲	▲
Quintile 5	464 (4.7)			▲	▲	▲	▲
Quintile 4	407 (7.5)	▽	▽		▲	▲	▲
Quintile 3	370 (3.2)	▽	▽	▽			▲
Quintile 2	366 (4.7)	▽	▽	▽			
Quintile 1	357 (4.3)	▽	▽	▽	▽		

The symbols indicate whether the average achievement of the school quintile was significantly higher (▲) than that of the comparison school quintile, or significantly lower (▽) than that of the comparison school quintile, and the blank blocks show where there was no statistically significant difference.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

13 We must interpret provincial achievement changes cautiously as provincial sample sizes are small and standard errors are therefore high.

Mathematics achievement and ability levels by school fee status

With the high levels of household poverty in the country, the South African Schools Act legislated the abolition of fees for learners attending schools in poorer communities (RSA, 1996c). Government therefore 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, and independent schools, pay fees, and their schools are designated as 'fee-paying'. Two-thirds of Grade 9 learners attend no-fee schools and one-third attend fee-paying schools (Refer to Reader's Guide).

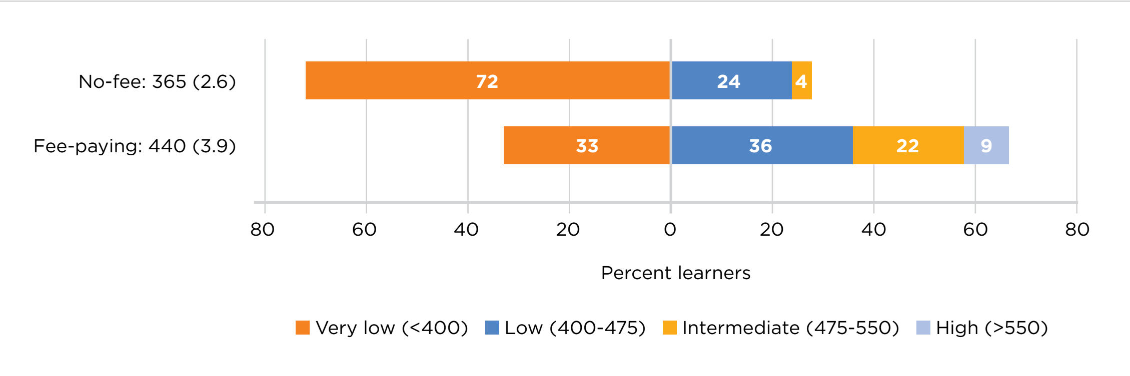
As expected, the differences in the material school and home conditions for learners attending no-fee and fee-paying schools lead to unequal achievement. In 2019, the average mathematics score for learners in no-fee schools was 365 (2.6), and in fee-paying schools it was 440 (3.9) (Figure 10). This means a gap of 75 points in mathematics achievement between learners attending no-fee and fee-paying schools.

Figure 10 also describes the percentage of learners reaching the different international achievement benchmarks. The percentage of learners to the right of the 0 point have acquired the basic knowledge and skills for Grade 9, while the percentage of learners to the left of the 0 point have not acquired basic knowledge and skills.

When the achievement scale scores are described in terms of ability levels, two out of three learners (67%) in fee-paying schools demonstrated that they had acquired basic mathematical knowledge and skills. It is noteworthy that nine percent of mathematics learners in fee-paying schools achieved scores above the High International Benchmark. These learners had the ability to apply their mathematical knowledge in complex situations.

Comparatively, in no-fee schools, just over one in four learners (28%) had acquired basic mathematical knowledge and skills. This means that 72 percent of learners in no-fee schools had not acquired the basic knowledge and skills for Grade 9.

Figure 10: Average mathematics scale score (SE) and percentage of learners reaching international achievement benchmarks, by school fee status (TIMSS 2019)



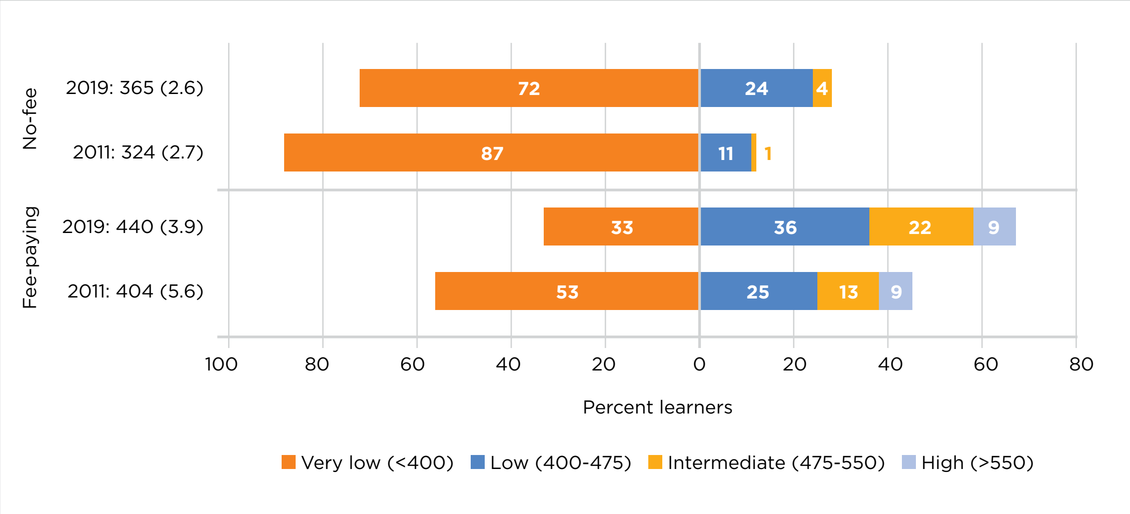
Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Trends in mathematics achievement and international achievement benchmarks by school fee status

With the improvement in national achievement scores from TIMSS 2011 to 2019, we would expect changes in both no-fee and fee-paying schools. Figure 11 reports the average scale scores and performance at the international achievement benchmarks for learners in no-fee and fee-paying schools in the 2011 and 2019 cycles. The average mathematics scores increased in no-fee schools by 41 points, from 324 to 365 points; and in fee-paying schools by 36 points, from 404 to 440 points.

In 2011, only 12 percent of learners in no-fee schools had acquired basic mathematical knowledge. This increased to 28 percent in 2019. The corresponding figures for fee-paying schools was 47 percent in 2011, increasing to 67 percent in 2019.

Figure 11: Trends in average mathematics scale score and percentage of learners reaching international benchmarks, by school fee status from 2011 to 2019



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

The following infographic provides a summary of South African Grade 9 learners' mathematics achievement and the achievement gaps that exist.

2.3. SUMMARY: MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

Mathematics performance

We can describe learners' TIMSS mathematics performance in two ways: using the scale scores and ability levels of learners. South Africa is one of the lower performing countries out of the set of TIMSS 2019 participating countries. The average mathematics scale score of 389 (2.3), though well below the TIMSS centrepoint of 500, was an increase of 17 points from the TIMSS 2015 cycle. The achievement increase from 2015 was statistically significant at the 95 percent confidence level.

Forty-one percent of learners demonstrated that they had acquired basic mathematics content knowledge and skills. It is noteworthy that four percent of Grade 9 South African learners demonstrated they had reached the higher international achievement benchmarks, meaning that they were able to apply their understanding and knowledge in a variety of complex situations.

Trend in mathematics performance

From TIMSS 1995 to 2003 there was no statistically significant difference in mathematics achievement. From 2003 to 2019 the country improved by 104 points (or one standard deviation) for mathematics. South African learners' average mathematics achievement therefore improved from 'very low' (1995, 1999 and 2003) to 'low' (2011, 2015 and 2019).

In terms of mathematical ability levels, 11 percent of learners demonstrated that they acquired basic knowledge for that grade in 2003. By 2019, this had increased almost fourfold to 41 percent.

While the achievement improvement is applauded, the trend analysis also raises a note of caution in relation to the pace of improvement. The average rate of mathematics improvement from 2003 to 2011 was 7.4 points per year. This slowed to 4.6 points per year for the 2011 to 2019 period. At this average achievement rate, even without considering the effects of loss of learning due to the coronavirus pandemic, it is unlikely that the country will meet the TIMSS 2023 mathematics achievement score target of 420 set in the Medium-Term Strategic Framework.

Trend in achievement inequality

The mathematics achievement distribution or achievement inequality, i.e. the achievement difference between the 5^{th} and 95^{th} percentiles, was 252 points in 2019. This was a decrease from the achievement distribution of 320 points in 2003. The decrease in achievement inequality was largely a result of improvements in the lowest achievement scores.

Provincial mathematics achievements

The best performing provinces for mathematics were the Western Cape and Gauteng, while the lowest performing provinces were the Eastern Cape and Limpopo.

The average mathematics scale score of all provinces, except the Northern Cape, increased significantly between 2011 and 2019.

The provincial mathematics achievement gap, measured by the difference between the highest and lowest provincial achievement, decreased from 89 points in 2011 to 77 points in 2019.

Mathematics performance by socioeconomic status of the school

South African achievement remained unequal. The average mathematics score for learners in no-fee schools was 365 (2.6) and in fee-paying schools it was 440 (3.9). This means that the mathematics achievement gap between no-fee and fee-paying schools was 75 points. Just over one in four learners (28%) in no-fee schools, compared to two in three learners (67%) in fee-paying schools, demonstrated that they had acquired basic mathematical knowledge and skills.

The next chapter focuses on Grade 9 learners' TIMSS science achievement and achievement gaps.

CHAPTER THREE

SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Science is the systematic study of the structure and behaviour of the physical, social and natural worlds through observation and experimentation. Many of our daily decisions are informed by our understanding of scientific knowledge. Learning science also has other benefits for learners such as improved problem-solving, critical thinking, and perseverance skills. Ultimately, these lifelong skills assist learners as they continue through their studies and into the competitive job market. Higher science achievement scores allow learners to continue their studies in science, contribute to innovation and technological developments, develop the competencies for their future workplace, and fully participate in society as informed and engaged citizens.

3.1. SCIENCE ACHIEVEMENT

Science achievement in an international context

South Africa, with Gauteng and Western Cape provinces as benchmarking participants, participated in TIMSS 2019. Figure 12 presents the average science scale scores with standard errors for all countries that participated in the eighth and ninth grade assessments, together with the scale score distribution underlying the average scale scores. In addition, we present the scale score range within each country by calculating the difference between the 5th and 95th percentiles.

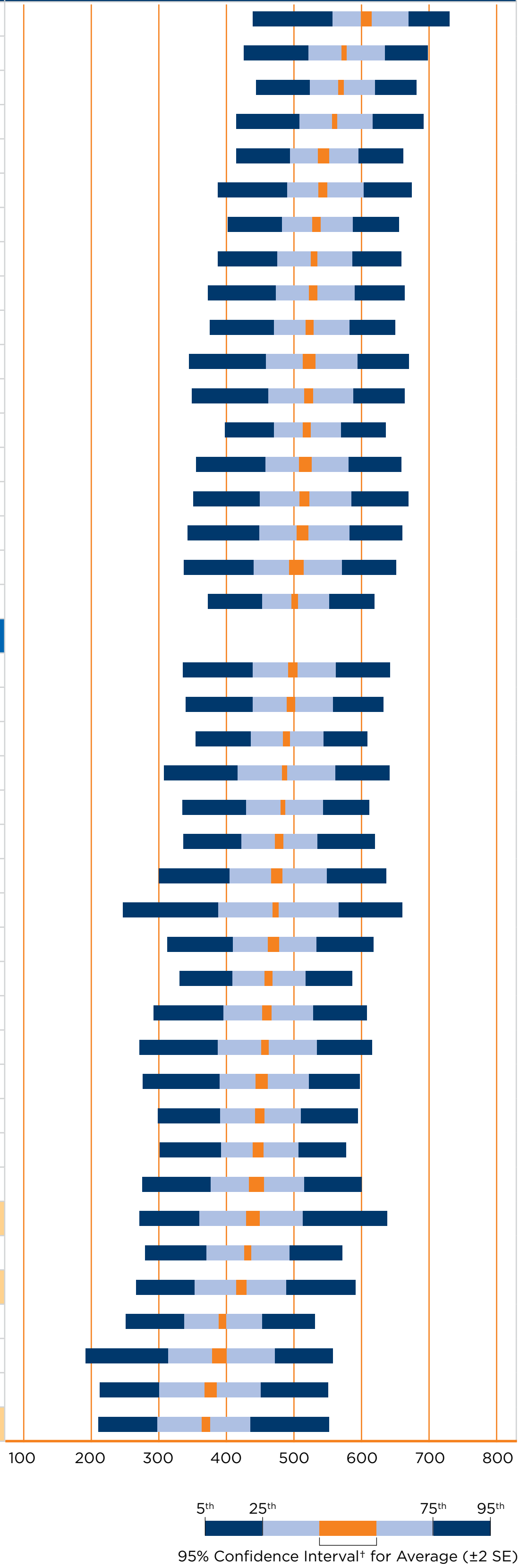
The countries are arranged from highest to lowest average science scale score. Singapore had the highest science achievement, followed by three other East Asian countries – Chinese Taipei, Japan, and Korea – who performed similarly. The fifth highest scoring country was the Russian Federation. The five lowest performing countries were Saudi Arabia, Morocco, Egypt, Lebanon and South Africa. The average scale scores of Lebanon and South Africa were not significantly different from each other.

The distributional inequality (difference between the 95th and 5th percentile scores) within countries ranged from 237 to 413 points. There were 21 countries where the distribution was less than 300 points, and 18 countries, including South Africa, with a distribution greater than 300 points. The countries with the highest distributional inequality were the United Arab Emirates, Egypt, Oman and South Africa (and Western Cape as a benchmarking participant), while those with the lowest distributional inequality were Japan, Portugal and Italy. Refer to Reader's Guide for how to read percentile graphs.

Figure 12: Average science scale score and distribution, by country (TIMSS 2019)

Country	Average Scale Score (SE)		Score difference between 5th and 95th percentiles
Singapore	608	(3.9)	291
Chinese Taipei	574	(1.9)	271
Japan	570	(2.1)	237
Korea, Rep. of	561	(2.1)	278
Russian Federation	543	(4.2)	247
Finland	543	(3.1)	285
Lithuania	534	(3.0)	254
Hungary	530	(2.6)	271
Australia	528	(3.2)	291
Ireland	523	(2.9)	274
United States	522	(4.7)	325
Sweden	521	(3.2)	315
Portugal	519	(2.9)	238
England	517	(4.9)	303
Turkey	515	(3.7)	318
Israel	513	(4.2)	318
Hong Kong, SAR	504	(5.2)	313
Italy	500	(2.6)	246
TIMSS Scale Centerpoint	500		
New Zealand	499	(3.5)	307
Norway (9)	496	(3.1)	292
France	489	(2.7)	254
Bahrain	486	(1.9)	334
Cyprus	484	(1.9)	277
Kazakhstan	478	(3.1)	283
Qatar	475	(4.4)	336
United Arab Emirates	473	(2.2)	413
Romania	470	(4.2)	304
Chile	462	(2.9)	256
Malaysia	460	(3.5)	316
Oman	457	(2.9)	343
Jordan	452	(4.7)	321
Iran, Islamic Rep. of	449	(3.6)	295
Georgia	447	(3.9)	275
Kuwait	444	(5.7)	324
Western Cape, RSA (9)	**439**	**(5.1)**	**366**
Saudi Arabia	432	(2.6)	291
Gauteng, RSA (9)	**422**	**(3.9)**	**324**
Morocco	394	(2.7)	280
Egypt	389	(5.4)	366
Lebanon	377	(4.7)	338
South Africa (9)	**370**	**(3.1)**	**341**

Science Achievement Distribution



Source: TIMSS 2019 international results report.

South African science achievement and learners reaching international achievement benchmarks

TIMSS describes science performance in two ways: scale scores and international achievement benchmarks. Figure 13 presents the average science achievement, at the ninth grade for South Africa, together with the scale score distribution. The average scale score of South African Grade 9 learners was 370 (SE 3.1). A total of 341 points separated the 5th and 95th percentiles, which was the fourth largest difference across the inequality distribution of all participating countries. Furthermore, the science distribution was higher than the mathematics distribution by close to 90 points.

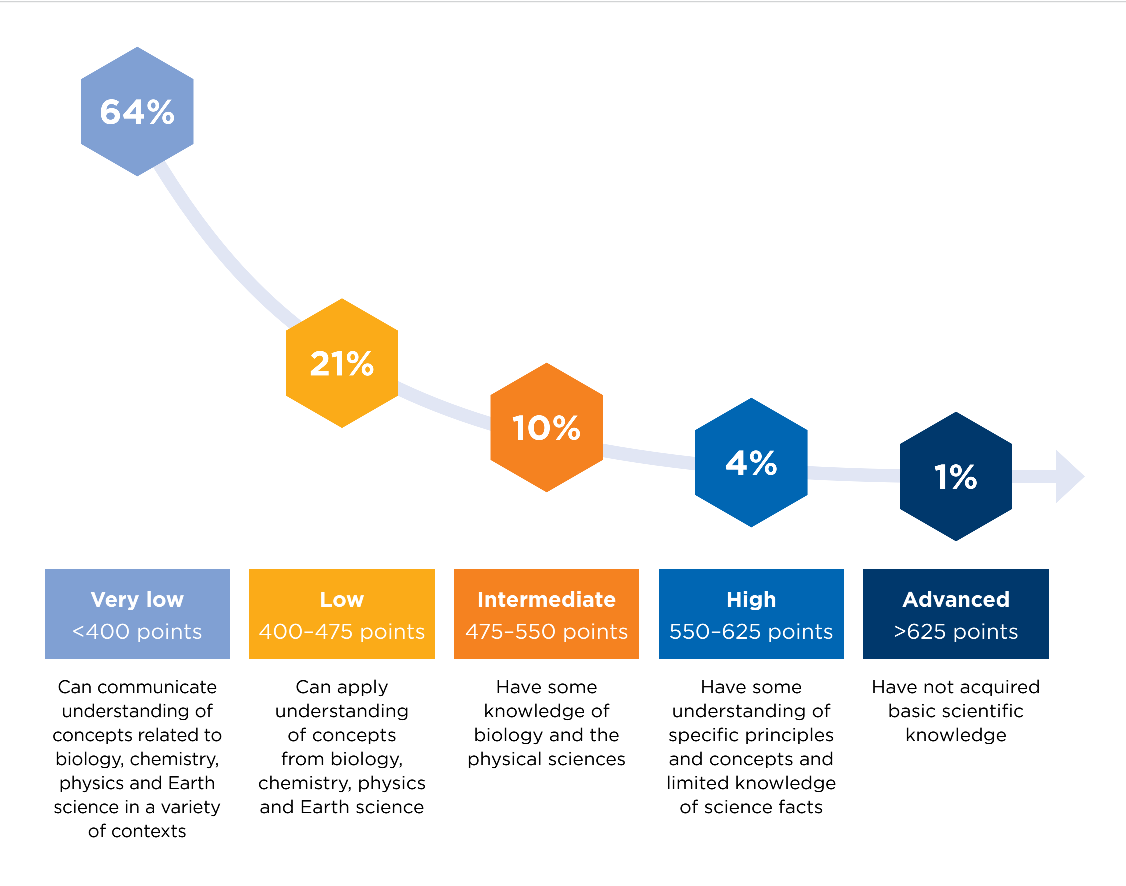
Figure 13: Average South African science achievement and scale score distribution (TIMSS 2019)

	Average Scale Score (SE)	Achievement Distribution
Science	370 (3.1)	

Source: TIMSS 2019 international results report.

Further insight into learner achievement is derived from describing their performance in relation to the international achievement benchmarks. Figure 14 provides the percentage of South African Grade 9 learners who reached each of the achievement benchmarks. The figure also presents the scale score range associated with each benchmark and provides a brief description of the abilities that learners would have demonstrated at each of these points.

Figure 14: Percentage of learners reaching science international benchmarks (TIMSS 2019)



Source: TIMSS 2019 South African Grade 9 dataset.

Cumulatively, 36 percent of South African Grade 9 learners demonstrated that they had acquired basic scientific knowledge, achieving 400 points or higher. In contrast, the majority of learners (64%) did not exhibit mastery of basic scientific knowledge. The country still has a long way to go to improve science knowledge and achievement. Learners reaching the higher benchmarks of achievement are assumed to be able to also do what is described in the lower achievement benchmarks.

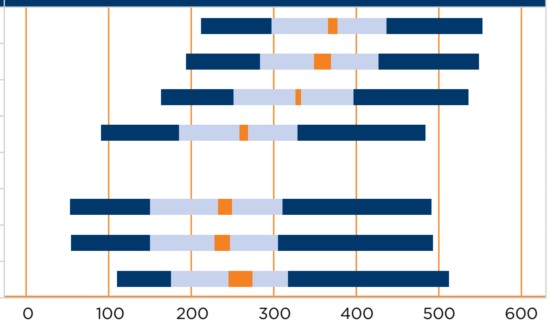
It is, however, noteworthy that one percent of South African science learners achieved at the advanced benchmark, attaining scores higher than 625 points. In subsequent analyses, we combine the *High* and *Advanced* International Benchmarks and use the term "High International Benchmark" to describe all achievements above 550 points.

Trends in science achievement from 1995 to 2019

TIMSS is the only South African trend measure dataset spanning 24 years of achievement. This section provides the trend analysis of average scale scores over the 1995 to 2019 period to measure national changes. Figure 15 presents the Grade 8 average science scale scores for the TIMSS 1995, 1999 and 2003 cycles, and the Grade 9 average science scale scores for the TIMSS 2003, 2011, 2015 and 2019 cycles.

Figure 15: Trends in average science scale score and distribution from 1995 to 2019

	Average Scale Score (SE)		Score difference between 5th and 95th percentiles	Mathematics Achievement Distribution
Gr9 TIMSS 2019	389	(2.3)	252	
Gr9 TIMSS 2015	372	(4.5)	286	
Gr9 TIMSS 2011	352	(2.5)	287	
Gr9 TIMSS 2003	285	(4.2)	320	
Gr8 TIMSS 2003	264	(5.5)	376	
Gr8 TIMSS 1999	275	(6.8)	372	
Gr8 TIMSS 1995	276	(6.7)	352	



Source: TIMSS South African Grade 8 and 9 datasets.

The South African average science scale scores were not significantly different in the TIMSS 1995, 1999 and 2003 cycles (Reddy et al., 2012). Between TIMSS 2003 and 2011, however, science performance increased by 64 points. There was a further increase of 26 points between TIMSS 2011 and 2015 (Reddy et al., 2016). This clear upward trajectory was sustained as science performance increased between TIMSS 2015 and 2019 by a further 12 points. The achievement differences between the 2003, 2011 and 2015 cycles were statistically significant at the 95 percent confidence level, and the difference between the 2015 and 2019 cycles was statistically significant at the 90 percent confidence level.

Taking a broad perspective of this 24-year period, from TIMSS 2003 to 2019, there was an increase of 102 points in the average science scores. In 1994, following apartheid education, the country started with very low science performance and abilities. Twenty-five years into democratic rule, the country recorded a one standard deviation increase in science achievement.

The trend measure also provides an opportunity to investigate the rate of improvement in science achievement. The average annual rate of achievement improvement from 2003 to 2019 was six points[14]. Closer analysis reveals that this achievement improvement rate was different for two eight-year periods: 2003 to 2011, and 2011 to 2019. In the first period, the average achievement improvement rate was 7.1 points per year, and for the second period it was 4.8 points per year. The slowing down of the improvement rate in achievement means it would take the country longer to reach the achievement levels to which it aspires.

14 We conducted data collection in 2002, 2011, 2015 and 2019.

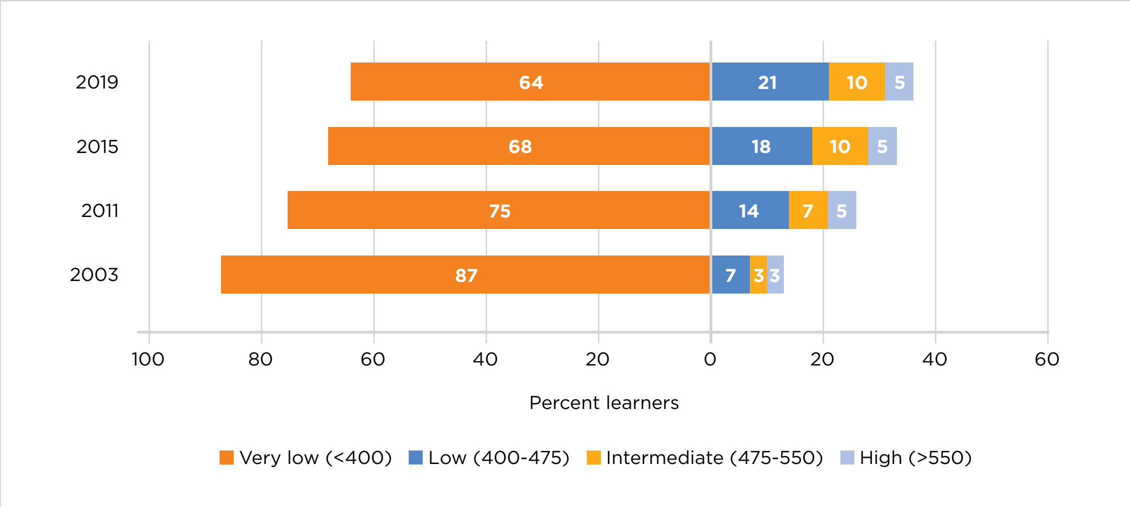
The achievement range (the difference of achievement at the 5th and 95th percentile) measures the extent of educational inequality in South Africa. Science achievement inequality decreased from 405 points in 2003 to 341 points in 2019, indicating a slight decrease in educational inequality. The highest achievement gains continued to be at the lower end of the achievement distribution, indicating that those with the lowest achievement scores, generally from poorer households and attending poorer schools, are improving the most. However, it is concerning that, since 2011, there has been very little improvement at the top end of the distribution curve.

Trends in learners reaching international achievement benchmarks from 2003 to 2019

In line with increases in the average science scale score from 2003 to 2019, the scientific ability levels of learners also improved. From 2003, with each subsequent TIMSS cycle, the percentage of learners demonstrating scientific abilities at the different benchmarks increased (Figure 16).

As illustrated in TIMSS 2003, South Africa started from a very low educational base with only 13 percent of learners demonstrating that they had acquired basic scientific skills and knowledge for their grade. By 2019, this increased almost threefold, with 36 percent of science learners demonstrating basic scientific abilities.

Figure 16: Trends in percentage of learners reaching international benchmarks from TIMSS 2003 to 2019



Source: Author’s own calculations from TIMSS South African Grade 9 dataset.

3.2. SCIENCE ACHIEVEMENT GAPS

South Africa is a large and diverse country. Thus, a single national achievement score does not tell the full story. Rather, better insights are provided through a more nuanced achievement story reported by locally relevant categories of (i) the province in which the school is located, and (ii) the socioeconomic status (SES) of the school. In this section we will report on results from TIMSS 2019, as well as trends between the 2011 and 2019 cycles.

Science achievement by province

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 policies and programmes in Grades R to 12. Provincial achievement estimates will provide information to monitor the progress across the nine departments.

The TIMSS 2019 provincial science achievement, with the standard error, and comparisons with other provinces, are presented in Table 4.

The top three performing provinces for science were the Western Cape with an average scale score of 439, Gauteng with 422, and Free State with 380. The average scale scores for six provinces, the Northern Cape, North West, KwaZulu-Natal, Mpumalanga, Eastern Cape and Limpopo, were lower than the national average score. Table 4 compares the average science achievement of each province with all other provinces and indicates whether the achievement score differences were statistically significant or not. The achievement scores of the top three provinces were significantly different from each other, as well as the other six provinces. Further, Table 4 describes the achievement comparison between provinces and highlights whether the difference was statistically higher, statistically lower, or where there was no statistically significant difference from the comparison province.

The difference in science achievement between the highest and lowest performing provinces was 108 points, quantifying the provincial science achievement gap.

Table 4: Average provincial science scale score and comparison between provinces (TIMSS 2019)

		Comparison province								
Province	Average Science Scale Score	Western Cape	Gauteng	Free State	Northern Cape	North West	KwaZulu-Natal	Mpumalanga	Eastern Cape	Limpopo
Western Cape	439 (5.1)		▲	▲	▲	▲	▲	▲	▲	▲
Gauteng	422 (3.9)	▽		▲	▲	▲	▲	▲	▲	▲
Free State	380 (7.4)	▽	▽		▲		▲	▲	▲	▲
Northern Cape	358 (5.9)	▽	▽	▽					▲	▲
North West	358 (8.9)	▽	▽						▲	▲
KwaZulu-Natal	352 (7.2)	▽	▽	▽						▲
Mpumalanga	350 (8.8)	▽	▽	▽						
Eastern Cape	334 (7.9)	▽	▽	▽	▽	▽				
Limpopo	331 (7.6)	▽	▽	▽	▽	▽	▽			

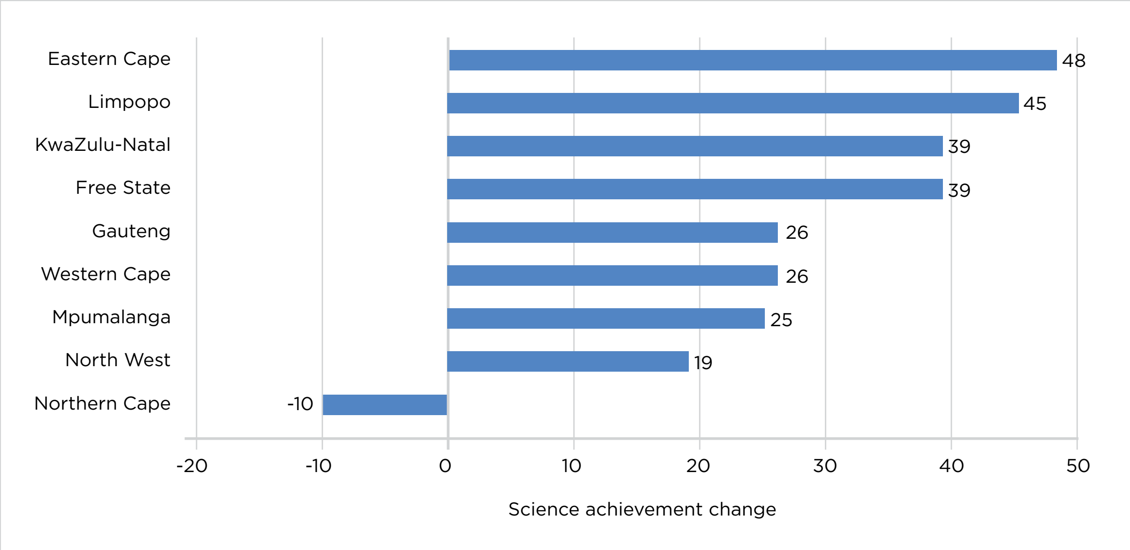
The symbols indicate whether the average achievement of the province was significantly higher (▲) than that of the comparison province, significantly lower (▽) than the comparison province, or that there was no statistically significant difference (blank blocks).

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Trends in science achievement by province from TIMSS 2011 to 2019

In line with the improvements in national achievement over time, we expect provincial science achievement to improve. We calculated the achievement difference for each of the provinces for the TIMSS 2011 to 2019 period. Bars to the right of the 0 line in Figure 17 represent an increase in achievement scores from 2011 to 2019, whereas those to the left indicate a decrease. The length of the bar reflects the amount by which the provincial achievement changed.

Figure 17: Change in average science scale score, by province from TIMSS 2011 to 2019



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

The highest achievement improvements, over the 2011 to 2019 period, were for the two lowest achieving provinces: Eastern Cape (by 48 points) and Limpopo (by 45 points). Northern Cape was the only province whose achievement decreased, by 10 points over this time. Our significance testing showed that the achievement difference, at the 95 percent confidence level, for all provinces between 2011 and 2019 was significant, except for the Northern Cape and North West provinces. The difference for the Western Cape was significant at the 90 percent confidence level[15].

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

15 We must interpret changes in provincial achievement cautiously as provincial sample sizes are small and standard errors are high.

Science achievement by socioeconomic status of the school

South African schools vary considerably with regard to the area in which they are located, and their level of access to infrastructure and resources. The DBE calculated a poverty index for each public school according to the income levels of the community around the school, the unemployment rate and the level of education of the community. Public schools are categorised into five (unequal) groups, called quintiles, with Quintile 1 being the most under-resourced schools in the most economically disadvantaged communities, and Quintile 5 being the best resourced schools (See Chapter 7 for further details).

Table 5 reports the average science achievement for schools in each quintile category, as well as for independent schools, and shows the comparisons between them. The average science achievement for learners in Quintile 1 schools was significantly lower than all other school categories. There was no significant difference observed between Quintile 2 and 3 school achievement. The average scale score for learners in Quintile 4 schools (399 points) was significantly higher than the scores in Quintile 1, 2 and 3 schools, and significantly lower than Quintile 5 and independent schools. The average scale score in Quintile 5 schools (475 points) was not statistically different from learners in independent schools (490 points), but their scores were significantly higher than the other school categories.

Table 5: Average science scale score, by school quintile rank and independent schools, and comparisons (TIMSS 2019)

		Comparison quintile					
Quintile Rank	Average Science Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	490 (10.2)			▲	▲	▲	▲
Quintile 5	475 (5.7)			▲	▲	▲	▲
Quintile 4	399 (10.3)	▽	▽		▲	▲	▲
Quintile 3	345 (4.2)	▽	▽	▽			▲
Quintile 2	337 (5.8)	▽	▽	▽			▲
Quintile 1	320 (5.4)	▽	▽	▽	▽	▽	

The symbols indicate whether the average achievement of the school quintile was significantly higher (▲) than that of the comparison school quintile, or significantly lower (▽) than that of the comparison school quintile, and the blank blocks show where there was no statistically significant difference.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

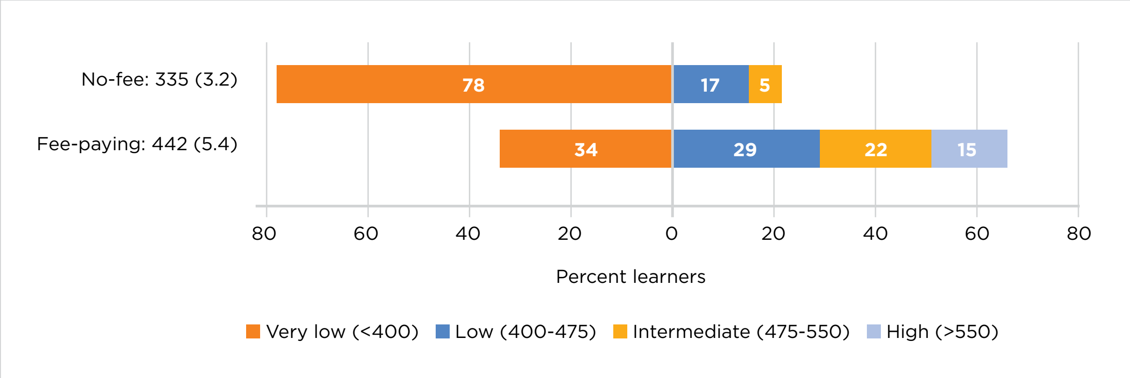
Science achievement and ability levels by school fee status

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, and independent schools, pay fees, and their schools are designated as 'fee-paying'. Two-thirds of Grade 9 learners attend no-fee schools and one-third attend fee-paying schools.

As expected, the differences in the material school and home conditions for learners attending no-fee and fee-paying schools lead to unequal achievement. In 2019, the average science score for learners in no-fee schools was 335 (3.2), and in fee-paying schools it was 442 (5.4). This means a science achievement gap of 107 points between learners attending no-fee and fee-paying schools.

Figure 18 also describes the percentage of learners reaching the different international achievement benchmarks. The percentage of learners to the right of the 0 point have acquired the basic knowledge and skills for Grade 9, while the percentage of learners to the left of the 0 point have not acquired basic science knowledge and skills.

Figure 18: Average science scale score and percentage of learners reaching international achievement benchmarks, by school fee status (TIMSS 2019)



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

When the achievement scale scores are described in terms of ability levels, two out of three learners (66%) in fee-paying schools demonstrated that they had acquired basic scientific knowledge and skills. It is noteworthy that 15 percent of science learners in fee-paying schools achieved scores above the High International Benchmark. These learners had the ability to apply their understanding of science concepts to everyday and abstract situations.

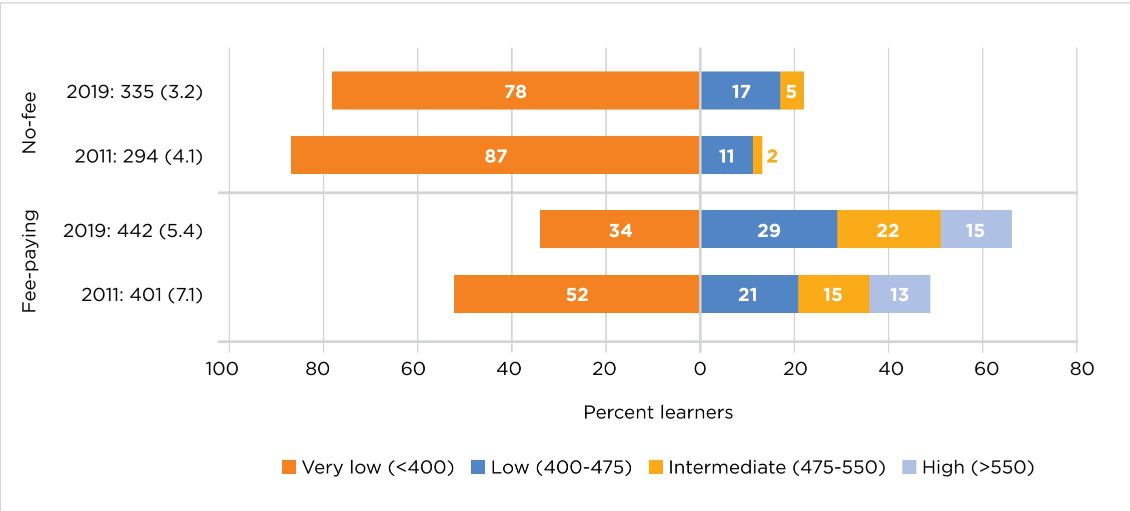
Comparatively, in no-fee schools, just over one in five learners (22%) showed that they had acquired basic scientific knowledge and skills. This means that 78 percent of learners in no-fee schools had not acquired the basic knowledge and skills for their grade.

Trends in science achievement and international benchmarks by school fee status

With the improvement in national achievement scores from TIMSS 2011 to 2019, we would expect changes in both no-fee and fee-paying schools. Figure 19 reports the average scale scores and performance at the international benchmarks for learners in no-fee and fee-paying schools in the 2011 and 2019 cycles. The average science scale scores increased in no-fee schools by 41 points, from 294 to 335 points; and in fee-paying schools by 40 points, from 401 to 442 points.

In 2011, only 13 percent of learners in no-fee schools demonstrated that they had basic scientific skills and knowledge. This increased to 22 percent in 2019. The corresponding figures for fee-paying schools were 48 percent in 2011, which increased to 66 percent in 2019.

Figure 19: Trends in average science scale score and percentage of learners reaching international benchmarks, by school fee status, in TIMSS 2011 and 2019



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

The following infographic presents a summary of South African Grade 9 learners' science achievement and the achievement gaps that are evident.

3.3. SUMMARY: SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Science performance

We can describe TIMSS science performance in two ways: using the scale scores and ability levels of learners.

South Africa is one of the lower performing countries out of the set of TIMSS 2019 participating countries. The average science scale score of 370 (3.1), though well below the TIMSS centrepoint of 500, was an increase of 12 points from the TIMSS 2015 cycle. The achievement increase from 2015 was statistically significant at the 90 percent confidence level.

Thirty-six percent of learners demonstrated that they acquired basic science content knowledge and skills. It is noteworthy that five percent of Grade 9 South African learners demonstrated they had reached the higher international achievement benchmarks, meaning that they were able to apply and communicate their understanding and knowledge in a variety of complex situations.

Trends in science performance

From TIMSS 1995 to 2003 there was no statistically significant difference in science achievement. From 2003 to 2019 the country improved by 102 points (or one standard deviation) for science. South African learners' average mathematics achievement therefore improved from 'very low' (1995, 1999 and 2003) to 'low' (2011, 2015 and 2019).

In terms of science ability levels, 13 percent of learners demonstrated that they had acquired basic knowledge in 2003. By 2019, this had increased almost threefold to 36 percent.

While the achievement improvement is applauded, the trend analysis also raises a note of caution in relation to the pace of improvement. The average rate of science improvement from 2003 to 2011 was 7.1 points per year. This slowed to 4.8 points per year for the 2011 to 2019 period. At this average achievement rate, even without considering the effects of loss of learning due to the coronavirus pandemic, it is unlikely that the country will meet the TIMSS 2023 science achievement score target of 420 set in the Medium-Term Strategic Framework.

Trends in achievement inequality

The science achievement distribution or achievement inequality, measured by the achievement difference between the 5th and 95th percentiles, was 341 points in 2019. This was a decrease, by 64 points, from the achievement distribution of 405 points in 2003. The decrease in achievement inequality was largely a result of improvements in the lowest achievement scores.

Provincial science achievements

The best performing provinces for science were the Western Cape and Gauteng, while the lowest performing provinces were the Eastern Cape and Limpopo. The average science scale score of six provinces increased significantly (at the 95 percent confidence level) between 2011 and 2019. The increase for the Western Cape was significant at the 90 percent confidence level, while the science achievement difference was not significant for the Northern Cape and North West provinces.

The provincial science achievement gap, measured by the difference between the highest and lowest provincial achievement, decreased from 127 points in 2011 to 108 points in 2019.

Science performance by socioeconomic status of the school

South African achievement remained unequal. The average science score for learners in no-fee schools was 335 (3.2) and in fee-paying schools it was 442 (5.4). This means that the science achievement gap between no-fee and fee-paying schools was 107 points.

Just over one in five learners (22%) in no-fee schools had acquired basic scientific knowledge and skills compared to two in three learners (66%) in fee-paying schools.

Section C of the report focuses on the mathematics and science curricula, highlighting learners' achievement by content domain, cognitive domain and question type.

SECTION C
THE CURRICULUM

The National Curriculum Statement (NCS) for Grades R to 12 stipulates the policy on curriculum and assessment. The NCS is based on principles of social transformation; active and critical learning; high knowledge and high skills; progression; human rights, inclusivity, environmental and social justice; valuing indigenous knowledge systems; and providing an education comparable to other countries (DBE, 2019a). The NCS includes the National Curriculum and Assessment Policy Statements (CAPS) for each approved school subject. The CAPS is a single, comprehensive, and concise policy document related to each subject (DBE, 2019b). Understanding the content of the NCS and CAPS documents provides insight into the performance of South African learners on the TIMSS 2019 assessment.

In Chapter 4, we describe the key skills and content outlined in the CAPS for mathematics and science. We draw from the international results, as well as HSRC analyses, to present the following for the mathematics and science assessments:

(i) Achievement and achievement gaps by content domain, as well as the extent of overlap between the TIMSS and CAPS;
(ii) Achievement and achievement gaps by cognitive domain; and
(iii) Achievement and achievement gaps by question type.

We used classical test theory (percentage correct of an item) and item response theory (IRT) to report on learner performance (refer to the Reader's Guide to learn more about the IRT).

CHAPTER FOUR

MATHEMATICS AND SCIENCE CURRICULA

In order to respond to the mathematics and science TIMSS 2019 assessment items, learners need to draw on three competences:

- Conceptual competence, which refers to familiarity with the content;
- Cognitive competence, which refers to the ability to draw on a range of cognitive skills; and
- Linguistic competence, which is the ability to read and understand the item (see Chapter 5).

The mathematics and science TIMSS assessments and assessment items are organised around two dimensions: content domains describing the subject matter to be assessed, and cognitive domains describing the thinking processes that learners use as they engage with the content. This allows learner performance to be described by both the content and cognitive perspectives (TIMSS 2019 Assessment Frameworks)[16]. We will first report our findings for mathematics and then for science.

4.1. MATHEMATICS CURRICULUM

Learners are introduced to numeracy concepts from Grade R, the reception year, and mathematics remains a key subject throughout the schooling years. The CAPS for Senior Phase (Grade 7 to 9) outlines the mathematical skills a learner should be acquiring, and the content areas covered in the curriculum (DBE, 2011a) (Annexure 2).

4.2. PERFORMANCE BY MATHEMATICS CONTENT AND COGNITIVE DOMAINS

The TIMSS Senior Phase mathematics assessment (taken at Grade 8 or 9) comprised 206 items. Approximately half of these items have appeared in previous TIMSS cycles, which allowed for a trend measure. The remaining half were newly introduced for the TIMSS 2019 cycle.

Achievement by content domain

TIMSS 2019 assessed four content areas in Senior Phase mathematics. Thirty percent of the assessment items were devoted to **number**, 30 percent to **algebra**, 20 percent to **geometry** and the remaining 20 percent to the **data and probability** content domain.

Table 6 reports the South African results for the mathematics content areas assessed and the percentage match between the TIMSS curriculum and CAPS document. We analysed educators' responses regarding whether the content had been taught to the learners by the time the TIMSS assessment was taken in order to calculate the percentage match.

Overall, the content of three-quarters of the TIMSS mathematics items were reported to have been taught before learners took the test. The degree of overlap between the TIMSS and South African curriculum was highest for number (97%), followed by geometry (86%), algebra (78%), and data and probability (54%).

Performance in the algebra content domain was significantly higher than the national average mathematics score; while achievement in geometry, as well as data and probability items, was significantly lower than the national average mathematics score. Achievement in the number content domain was the same as the national score. There was no noticeable relationship between the extent of curriculum coverage and achievement.

16 https://timssandpirls.bc.edu/timss2019/frameworks/

Table 6: Average mathematics achievement by content area, and match between TIMSS and CAPS curriculum

	Percentage match between TIMSS and CAPS	Mathematics scale score (SE)	Difference from national mean score
National: All mathematics items (206 items)	76	389 (2.3)	
Algebra (61 items)	78	401 (2.5)	+12 points*
Number (63 items)	97	390 (2.3)	+1 point
Geometry (43 items)	86	376 (2.7)	-13 points*
Data and Probability (39 items)	54	370 (2.4)	-19 points*

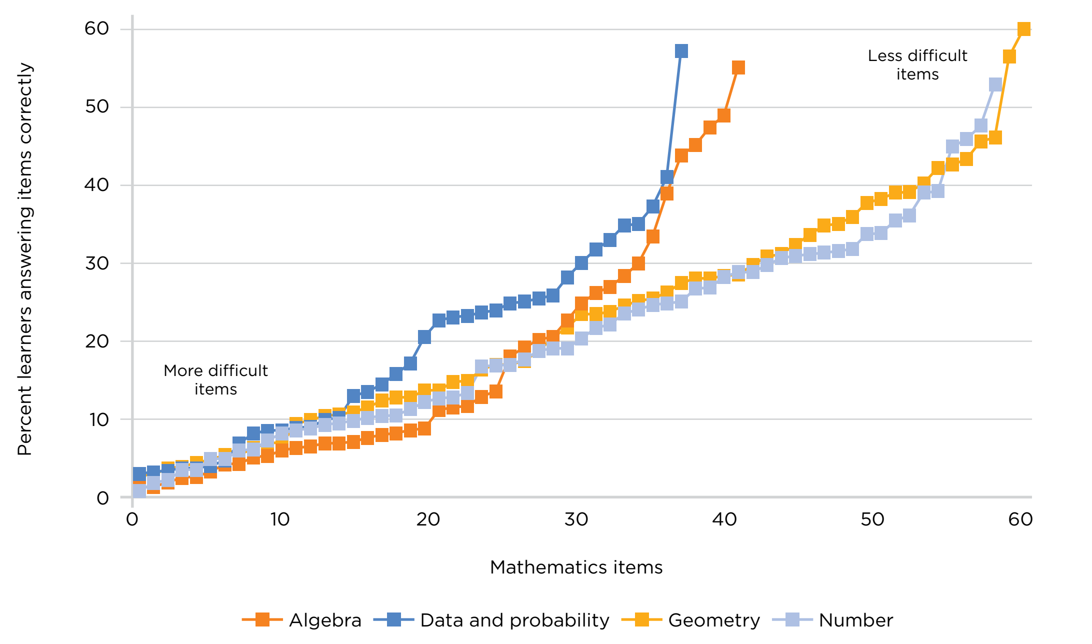
* Statistically significant achievement difference from national mean score.

Source: TIMSS 2019 South African Grade 9 dataset.

Next, we plotted a graph of the percentage of learners who gave correct responses for each item, in each of the four content areas, and arranged them from lowest to highest frequency correct. The item percent correct (refer to Reader's Guide) graph is shown in Figure 20.

A higher percentage of learners provided correct responses to items in the number (average of 22% correct) and algebra (21%) content domains, while fewer learners answered items correctly in the data and probability (19%), and geometry (15%) domains.

Figure 20: Percentage of learners who answered items correctly per mathematics content domain



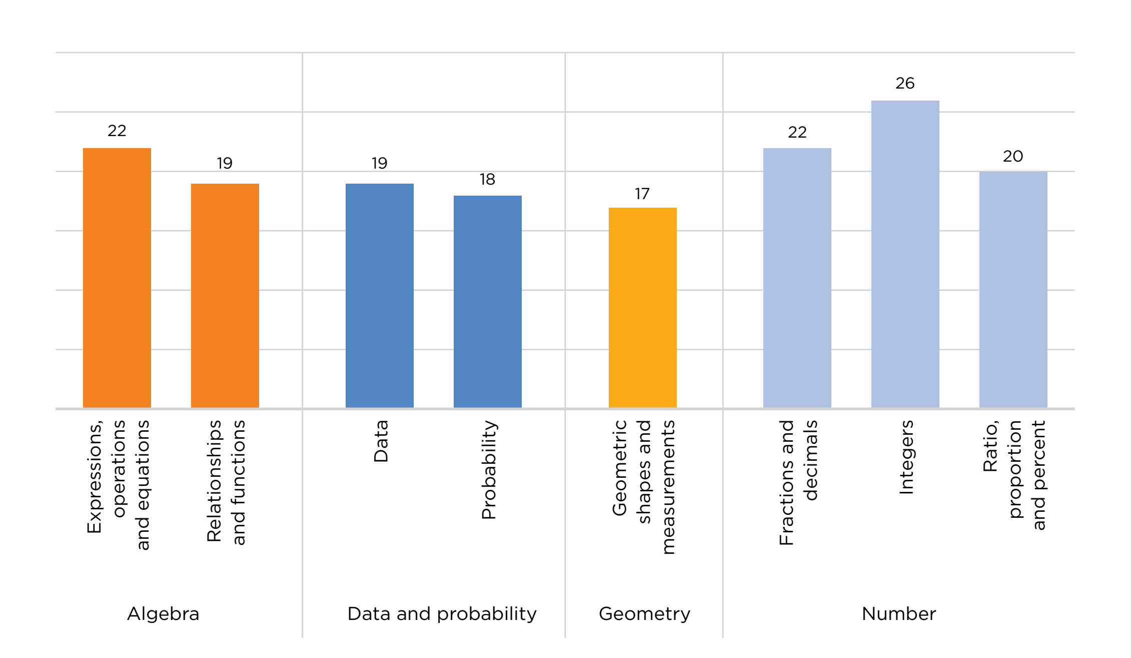
	All Items	Algebra	Data and probability	Geometry	Number
Average South African percent correct	19	21	19	15	22
International percent correct[17]	33	33	34	28	36

Source: TIMSS 2019 South African Grade 9 dataset.

17 These figures were calculated from the 17 countries that participated in paper-TIMSS.

The content domains were further disaggregated into eight mathematics topic areas. The percentage of learners that answered items correctly in each topic area is reported in Figure 21. Learners performed best in the topic areas of integers (26%), and fractions and decimals (22%). The lowest performance was in the topic areas of probability (18%), and geometric shapes and measurements (17%).

Figure 21: Mathematics topic areas and the average percent correct



Source: TIMSS 2019 South African Grade 9 dataset.

Achievement by cognitive domain

TIMSS classifies the achievement items into three hierarchically organised cognitive domains: **knowing**, **applying** and **reasoning** (refer to Reader's Guide). In the TIMSS 2019 assessment, one-third of items were classified as knowing, while two-thirds of the items were at the higher cognitive levels of applying and reasoning. TIMSS is not a simple assessment, and learners are required to display a range of cognitive skills.

TIMSS cognitive domains

The three hierarchically organised cognitive domains are knowing, applying and reasoning. Knowing covers the facts, concepts, and procedures learners need to know. Applying focuses on the ability of learners to apply knowledge and conceptual understanding to solve problems or answer questions. Reasoning goes beyond solving routine problems to encompass unfamiliar situations, complex contexts, and multistep problems.

Table 7 reports the percentage of items in the TIMSS assessment by the cognitive domains and the average mathematics achievement score for each domain. The achievement score for knowledge items was significantly lower than the national mathematics mean by 10 points, whereas the score for reasoning items was significantly higher than the national mean by 6 points.

Table 7: Mathematics achievement by TIMSS cognitive domain

	Percent items in TIMSS curriculum	Mathematics scale score (SE)	Difference from the national mean score
National: All mathematics items (206 items)	100	389 (2.3)	
Knowing (64 items)	35	379 (3.1)	-10*
Applying (96 items)	40	393 (2.1)	+4
Reasoning (46 items)	25	395 (2.5)	+6*

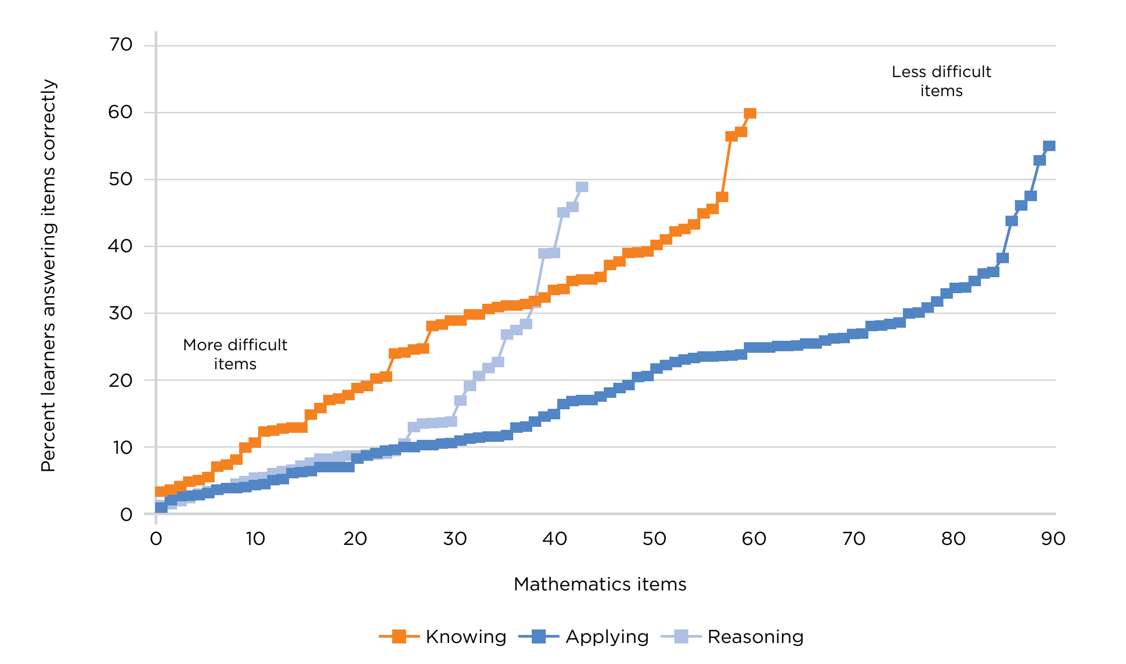
* Statistically significant achievement difference from national mathematics mean score.

Source: TIMSS 2019 South African Grade 9 dataset.

We plotted the percentage of learners who gave correct responses for each item in each of the three cognitive domains and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 22 (see Reader's Guide on how to interpret the Item Percent Graph).

The average item percent correct was highest for the knowing cognitive domain (average of 26% correct), followed by applying (18%) and then reasoning (14%).

Figure 22: Percentage of learners who answered items correctly per mathematics cognitive domain



	All Items	Knowing	Applying	Reasoning
Average South African percent correct	19	26	18	14
International percent correct[18]	33	41	32	25

Source: TIMSS 2019 South African Grade 9 dataset.

4.3. SCIENCE CURRICULUM

South African learners are first introduced to the natural sciences and technology subject in Grade 4. From Grade 7 onwards, learners are taught natural sciences as a subject. South Africa follows an integrated science curriculum that is set out in the CAPS document (DBE, 2011b) (Annexure 2).

18 These figures were calculated from the 17 countries that participated in paper-TIMSS.

4.4. PERFORMANCE BY SCIENCE CONTENT AND COGNITIVE DOMAINS

The TIMSS Senior Phase science assessment (taken at Grade 8 or 9) comprised 220 items. Approximately half of these items had appeared in previous TIMSS cycles, which allowed for a trend measure. The remaining half were newly introduced for the TIMSS 2019 cycle.

Achievement by content domain

TIMSS 2019 assessed four content areas in Senior Phase science. Thirty-five percent of the assessment items were devoted to **biology**, 20 percent to **chemistry**, 25 percent to **physics** and the remaining 20 percent to **Earth science**.

Table 8 reports the South African results for the science content areas assessed and the percentage match between the TIMSS curriculum and CAPS document. We analysed educators' responses regarding whether the content had been taught to the learners by the time the TIMSS assessment was taken in order to calculate the percentage match.

Overall, the content of three-quarters of the TIMSS science items were reported to have been taught before learners took the test. The degree of overlap between the TIMSS and the South African curriculum was highest for chemistry (84%) and biology (83%), followed by physics (72%) and Earth science (55%). In the South African curriculum, the Earth science topics are taught in both the natural sciences and geography subject areas, possibly explaining why the overlap between the TIMSS and CAPS curriculum is low (in TIMSS, educators are only asked about the content taught in science).

Performance in the physics content domain was significantly higher than the national average science score by 11 points, while achievement in biology and Earth science was significantly lower than the national average score, by four and 11 points, respectively. There was no noticeable relationship between the extent of curriculum coverage and achievement.

Table 8: Science achievement by content area and match between TIMSS and CAPS curriculum

	Percent match between TIMSS and CAPS	Science scale score (SE)	Difference from national mean score
National: All science items (220 items)	76	370 (3.1)	
Physics (52 items)	72	381 (3.0)	+11*
Chemistry (42 items)	84	372 (4.2)	+2
Earth science (42 items)	55	366 (3.2)	-4*
Biology (75 items)	83	359 (3.0)	-11*

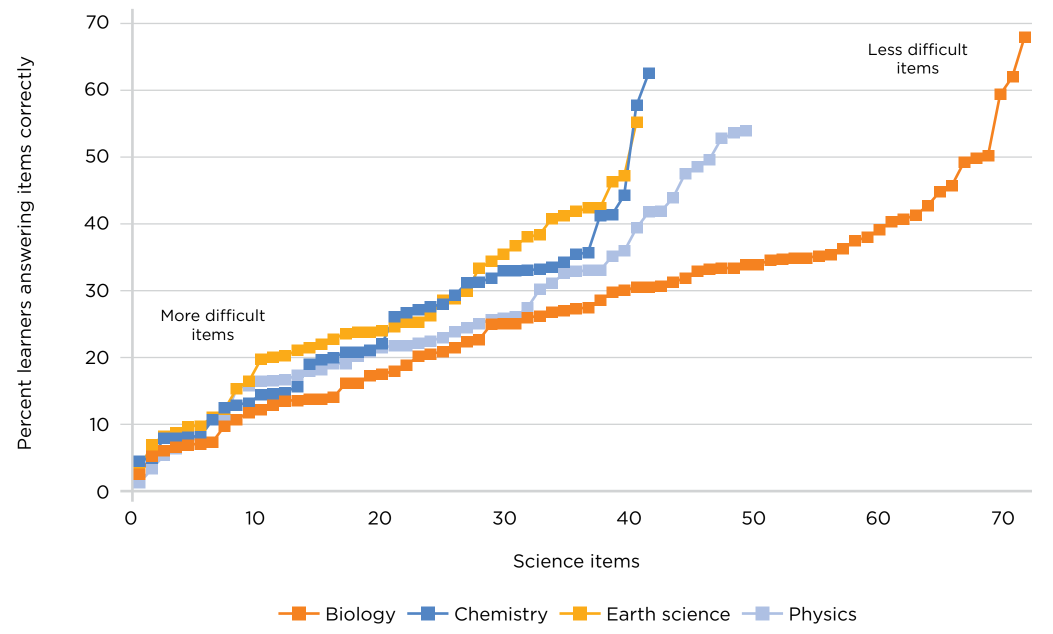
* Statistically significant achievement difference from national mean score.

Source: TIMSS 2019 South African Grade 9 dataset.

Next, we plotted a graph of the percentage of learners who gave correct responses for each item, in each of the four content areas, and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 23 (see Reader's Guide on how to interpret the graph).

The percentage of learners who answered items correctly in each of the content domains was similar for Earth science (average of 26% correct), biology (25%) and physics (25%), and slightly lower for chemistry (23%).

Figure 23: Percentage of Grade 9 learners who answered items correctly per science content domain



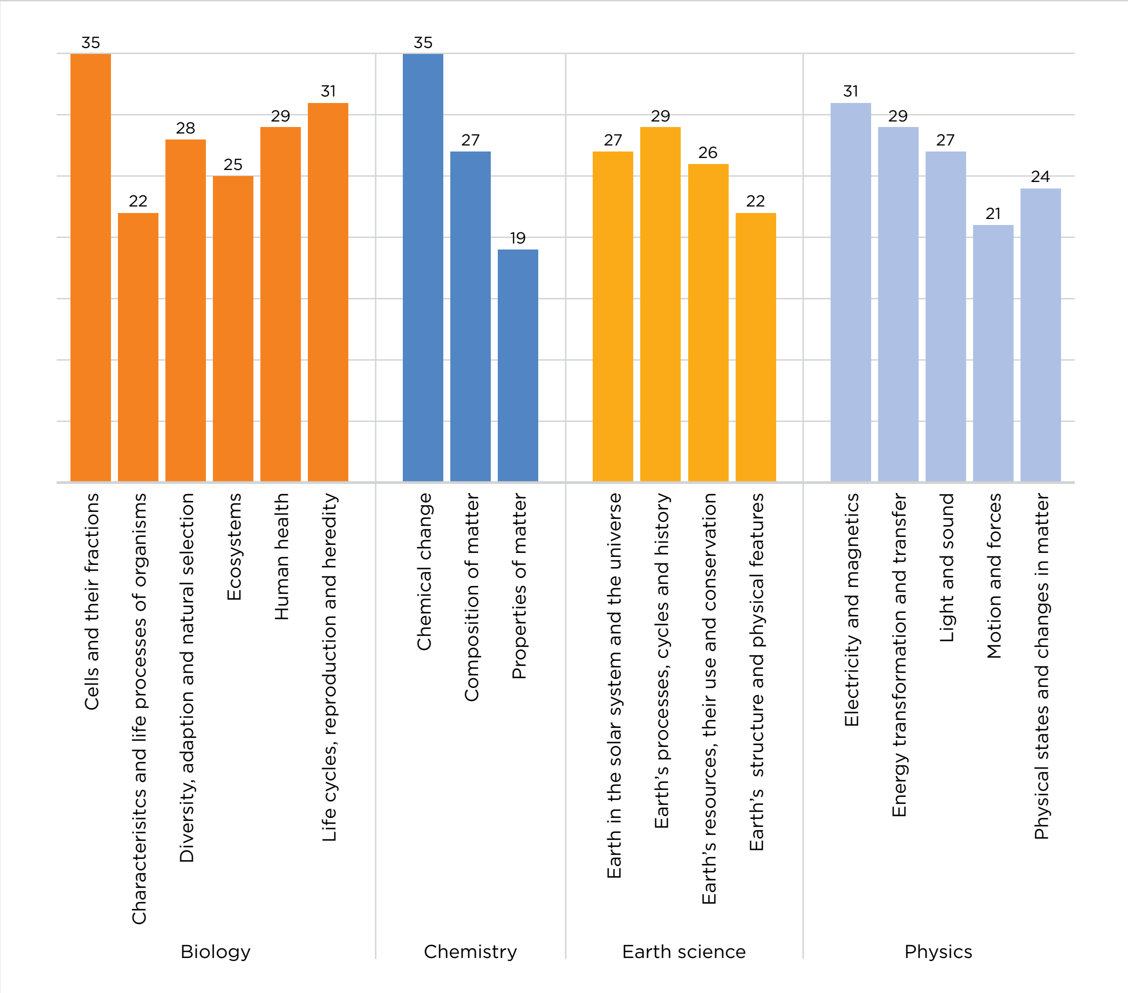
	All items	Biology	Chemistry	Earth science	Physics
Average South African percent correct	25	25	23	26	25
International percent correct[19]	38	40	35	38	37

Source: TIMSS 2019 South African Grade 9 dataset.

The content domains were further disaggregated into 18 science topic areas. We calculated the average percentage of learners who answered items correctly in each topic areas, and this is reported in Figure 24. Learners performed best in the topic areas of chemical change (35%), cells and their functions (35%), and electricity and magnetism (31%). The lowest performance was in Earth structure and physical features (22%), motion and forces (21%), and properties of matter (19%).

19 These figures were calculated from the 17 countries that participated in paper-TIMSS.

Figure 24: Science topic areas and the average percentage correct



Source: TIMSS 2019 South African Grade 9 dataset.

Achievement by cognitive domain

TIMSS differentiates the achievement items into three hierarchically organised cognitive domains: **knowing**, **applying** and **reasoning** (see Reader's Guide). In the TIMSS 2019 science assessment, one-third of items were classified as knowing, and two-thirds of the items were at the higher cognitive levels of applying and reasoning.

Table 9 reports the percentage of items in the TIMSS assessment by the cognitive domains and the average science achievement score for each domain. The science scale scores for knowledge and reasoning items were significantly lower than the science mean score, by nine and eight points, respectively; and the science scale score for applying items was significantly higher than the national mean score by seven points.

Table 9: Science achievement by TIMSS cognitive domain

	Percent items in TIMSS curriculum	Science scale score (SE)	Difference from national mean score
National: All science items (220 items)	100	370 (3.1)	
Knowing (75 items)	35	361 (3.2)	-9*
Applying (80 items)	35	377 (2.9)	+7*
Reasoning (56 items)	30	362 (3.0)	-8*

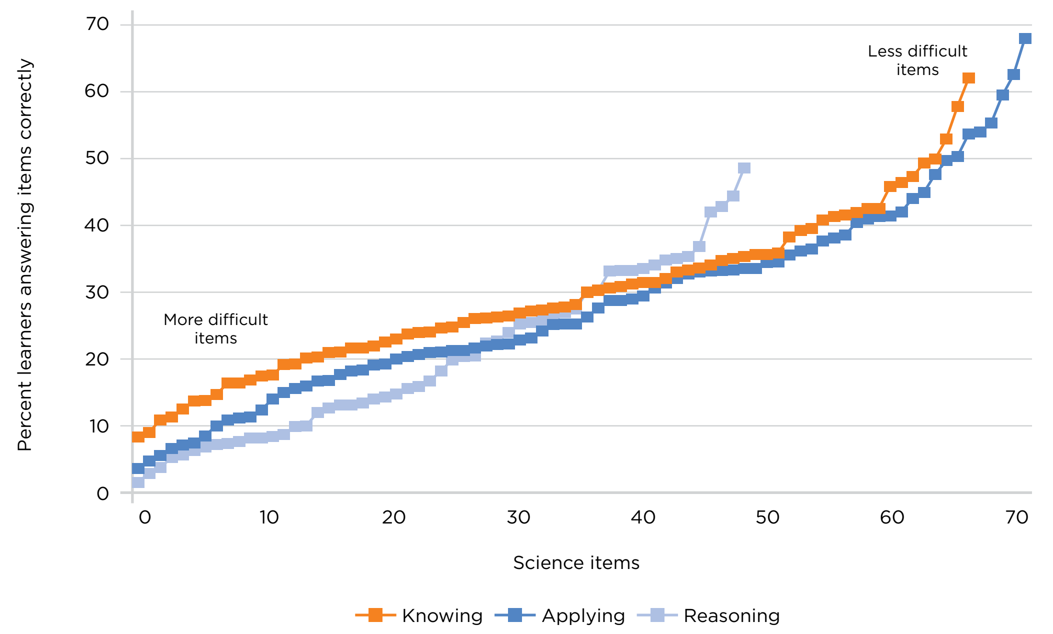
* Statistically significant achievement difference from overall mean score.

Source: TIMSS 2019 South African Grade 9 dataset.

We plotted the percentage of learners who gave correct responses for each item in each of the three cognitive domains and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 25 (see Reader's Guide on how to interpret the graph).

The average item percent correct for each of the cognitive domains was highest for the knowing cognitive domain (average of 28% correct), followed by applying (25%) and reasoning (19%).

Figure 25: Percentage of Grade 9 learners who answered items correctly per cognitive domain



	All Items	Knowing	Applying	Reasoning
Average South African percent correct	25	28	25	19
International percent correct[20]	38	41	38	34

Source: TIMSS 2019 South African Grade 9 dataset.

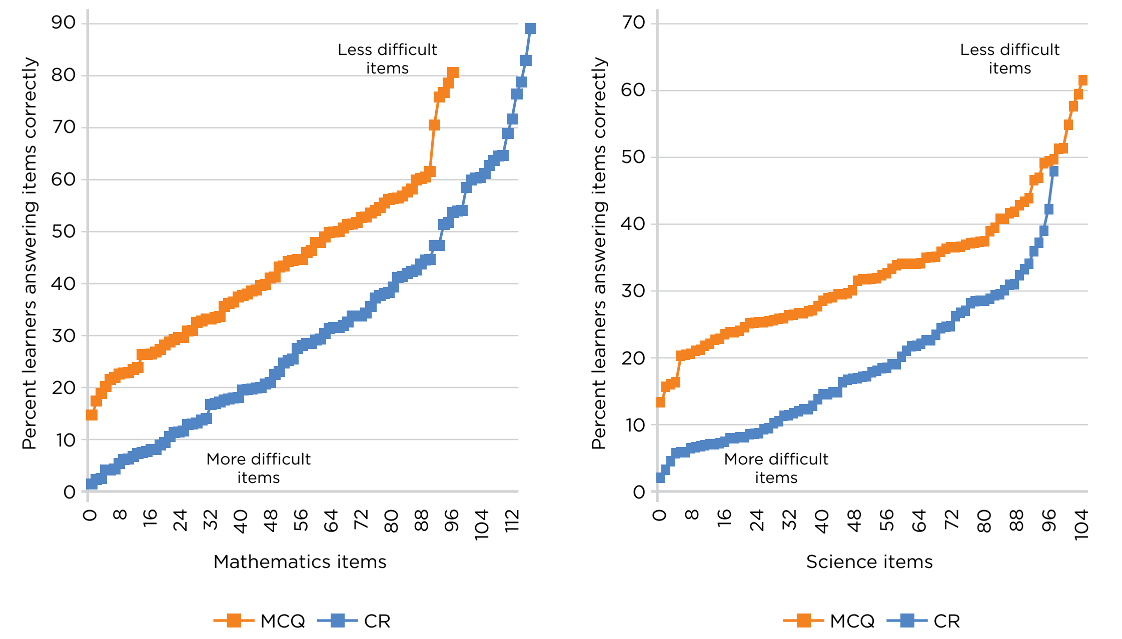
4.5. PERFORMANCE BY QUESTION TYPE

The TIMSS assessment consisted of two general item formats: selected response items (also known as multiple-choice questions (MCQs)) and constructed response items. For items involving selected responses, learners chose their answer from a set of four options; and for the constructed response items, learners wrote their own responses. This may have included, for example, performing a calculation or writing an explanation. In broad terms, 50 percent of TIMSS items were in the selected response format and 50 percent were constructed response items.

20 These figures were calculated from the 17 countries that participated in paper-TIMSS.

We calculated the percentage of learners who responded correctly to each of the selected and constructed response items. The graphs are shown in Figure 26, along with the percentage of correct responses for mathematics and science items in both formats.

Figure 26: Percentage of South African learners who answered mathematics and science selected response items (MCQs) and constructed response items correctly



	Mathematics average percent correct	Science average percent correct
Selected Response Items (MCQs)	29	33
Constructed Response Items (CR)	14	20

Source: TIMSS 2019 South African Grade 9 dataset.

Learners performed better on items requiring a selected (multiple choice) response (29 percent for mathematics and 33 percent for science answered these items correctly), than on items where learners had to construct a response (14 percent items correct for mathematics and 20 percent for science). Analysis of learner responses to constructed items showed that learners had difficulty in writing coherent sentences and explanations or making an argument.

In the infographic that follows, we provide a summary of the mathematics and science achievement gaps in TIMSS 2019 by content domain, cognitive domain and question type.

4.6. SUMMARY: MATHEMATICS AND SCIENCE CURRICULA

Achievement gaps by mathematics content domains

The content covered by three-quarters of the TIMSS mathematics items was reported to have been taught at school before learners took the test.

The degree of overlap between the TIMSS and South African mathematics curriculum was highest for number (97%), followed by geometry (86%), algebra (78%), and data and probability (54%).

For the mathematics content areas, the average mean score for algebra was significantly higher than the national average score, while geometry as well as data and probability content proved more difficult for learners, and they achieved significantly lower average scores than the national mean score. Achievement in the number content area was the same as the national mean score. There was, nevertheless, no noticeable relationship between the extent of curriculum coverage and the corresponding achievement scores.

Regarding content topic areas, learners performed best in the integer topic area, followed by fractions and decimals; and expressions, operations and equations. The lowest performance was in the topic areas of probability, and geometric shapes and measurements.

Achievement gaps by science content domains

The content covered by three-quarters of the TIMSS science items was reported to have been taught at school before learners took the test. The science TIMSS assessments were divided across several content areas which were further divided into topic areas.

The degree of overlap between the TIMSS and South African science curriculum was highest for chemistry (84%) and biology (83%), followed by physics (72%) and Earth science (55%).

Performance in the physics content domain was significantly higher than the national average science score, while achievement in biology and Earth science was significantly lower than the national average score. Achievement in the chemistry content area was the same as the national average score. There was no noticeable relationship between the extent of curriculum coverage and corresponding achievement scores.

Regarding content topic areas, learners performed best in chemical change, and cells and their functions. The lowest performance was in motion and forces, and properties of matter.

Achievement gaps by mathematics and science cognitive demand

TIMSS differentiates the achievement items into three hierarchically organised cognitive domains: knowing, applying and reasoning. In the TIMSS 2019 mathematics and science assessment, one-third of items were classified as knowing, and two-thirds of the items were at the higher cognitive levels of applying and reasoning.

The average mathematics scale score for knowledge items was significantly lower than the average national mathematics mean, whereas the scale score for reasoning items was significantly higher than the average national mean score. Achievement on applying items was not significantly different from the national mean score.

The average science scale scores for knowledge and reasoning items were significantly lower than the average national science score, while the science scale score for applying items was significantly higher than the average national science score.

Achievement gaps by question type

As would be expected, learners performed better on items requiring a selected (multiple choice) response and had greater difficulty on items where they had to construct a written response. Learners had difficulty in writing coherent sentences and explanations or making an argument.

In Section D, we explore aspects of the home environment, and learner characteristics and attitudes that are associated with learners' achievement.

SECTION D

THE HOME ENVIRONMENT AND LEARNER CHARACTERISTICS RELATED TO ACHIEVEMENT

In addition to measuring mathematics and science achievement, TIMSS seeks to understand the contexts in which learners live and learn. The global literature highlights that differences in achievement are associated with individual, home, classroom and school characteristics.

Section D reports on learners' home environments and learner characteristics, and their association with mathematics and science achievement. In addition to completing an achievement booklet, each learner completed a Learner Background Questionnaire. This data forms the basis of this section.

This section consists of two chapters:

(i) Chapter 5 focuses on two aspects: (i) Learner characteristics of gender, language spoken and age, and the relationship with achievement; and (ii) Learners and their home environment, i.e. home assets, home educational resources, and home support for learning, and the relationship with achievement.

(ii) Chapter 6 discusses learner attitudes towards mathematics and science. We report on the attitudes of 'Like Learning' mathematics and science; 'Valuing' mathematics and science, and 'Confidence' in mathematics and science.

Within each chapter, we report the national statistics and, where relevant, we disaggregate achievement by public fee-paying, no-fee, and, at times, independent schools. We must note that high standard errors exist with the latter, as there are a smaller number of participating independent schools. Due to the small number of independent schools, we largely combine the group of public fee-paying and independent schools to report for fee-paying schools.

CHAPTER FIVE

LEARNERS AND THEIR HOME ENVIRONMENT

There are many ways in which a learner's individual characteristics and home environment are related to achievement outcomes. This chapter will first report on the individual level characteristics of learners' gender, language spoken at home, and age, and the relationship with mathematics and science achievement. We will then report on the (i) availability of home assets, as well as the changes in reported home assets from 2003 to 2019; (ii) access to home educational resources; and (iii) home support for learning. Each of these aspects are considered in relation to learners' achievement.

5.1. A PROFILE OF LEARNERS

Learners' gender and achievement

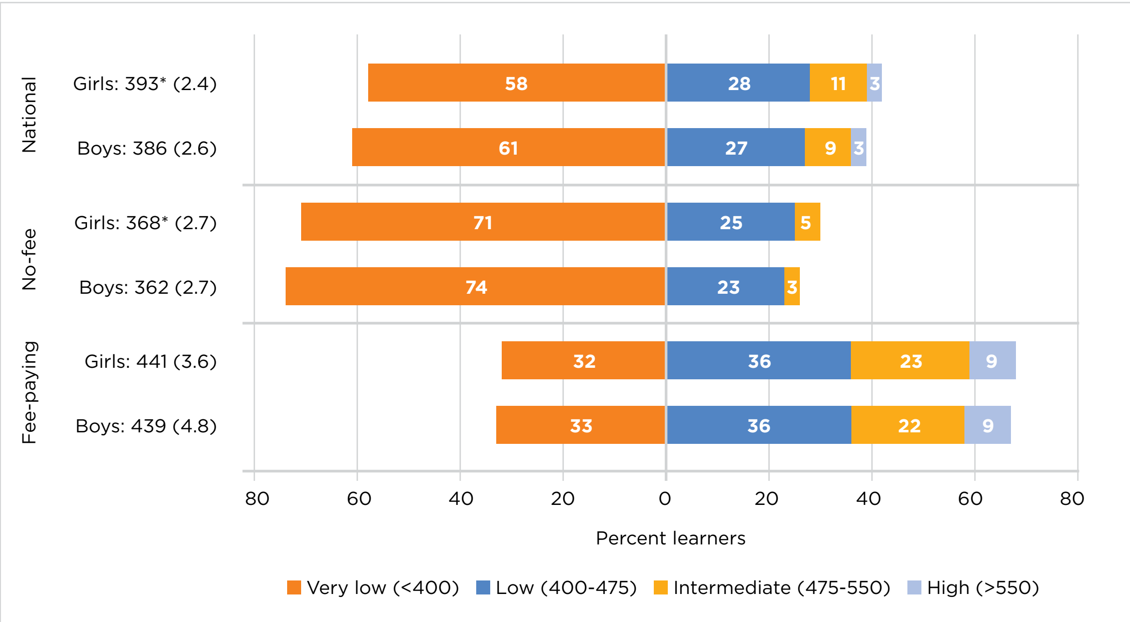
International evidence on the relationship between gender and achievement is mixed, not only across countries, but also within countries. Gender differences in educational experiences in South Africa are complex and multidimensional and intersect with race and socioeconomic status (SES). Girls tend to stay enrolled longer in schools (Zuze & Beku, 2019) and have better educational outcomes (DBE, 2020b). We examine the gender achievement patterns for South Africa as a whole, as well as in the contexts of higher and lower economic affluence using the fee status of the school to differentiate levels of affluence.

Gender and mathematics achievement

Among the TIMSS countries participating at Grade 9, girls achieved significantly higher mathematics scores in seven countries; there was no significant gender difference in achievement in 26 countries; and boys had significantly higher mathematics achievement than girls in six countries.

The South African mathematics achievement scores and achievement benchmarks, for girls and boys nationally, and for fee-paying and no-fee schools are presented in Figure 27. The average achievement score for girls of 393 (2.4) was significantly higher than for boys at 386 (2.5). Girls outscored boys by a statistically significant six points in no-fee schools. While girls also outscored boys by two points in fee-paying schools, this difference was not statistically significant.

Figure 27: Average mathematics scale score and percentage of learners reaching international benchmarks, by school status and gender (TIMSS 2019)



* Statistically significant achievement difference between boys and girls.

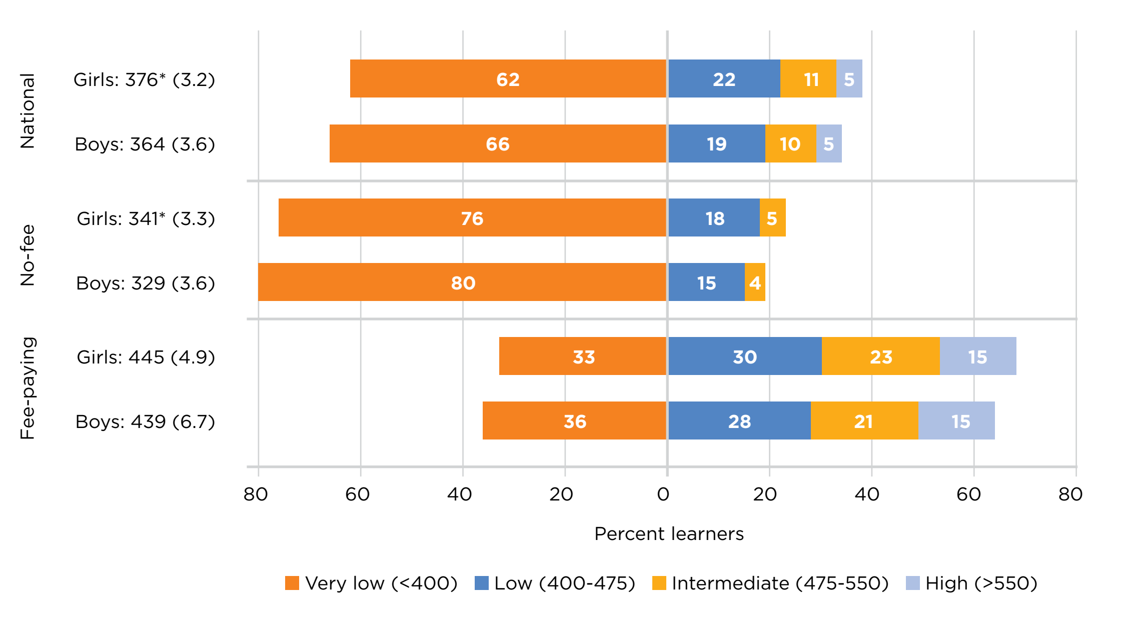
Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Gender and science achievement

Among the TIMSS countries participating at Grade 9, girls achieved significantly higher science scores in 15 countries, there was no significant gender difference in achievement in 18 countries, and boys had significantly higher science achievement than girls in six countries.

The South African science achievement scores and achievement benchmarks, for girls and boys nationally, and for fee-paying and no-fee schools are presented in Figure 28. Nationally, the average scale scores for girls of 376 (3.2) was significantly higher than for boys at 364 (3.6). Girls significantly outscored boys in no-fee schools by 12 points. While girls also outscored boys in fee-paying schools, the six-point difference was not statistically significant.

Figure 28: Science achievement and percentage of learners reaching international benchmarks, by school status and gender (TIMSS 2019)



* Statistically significant achievement difference between boys and girls.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

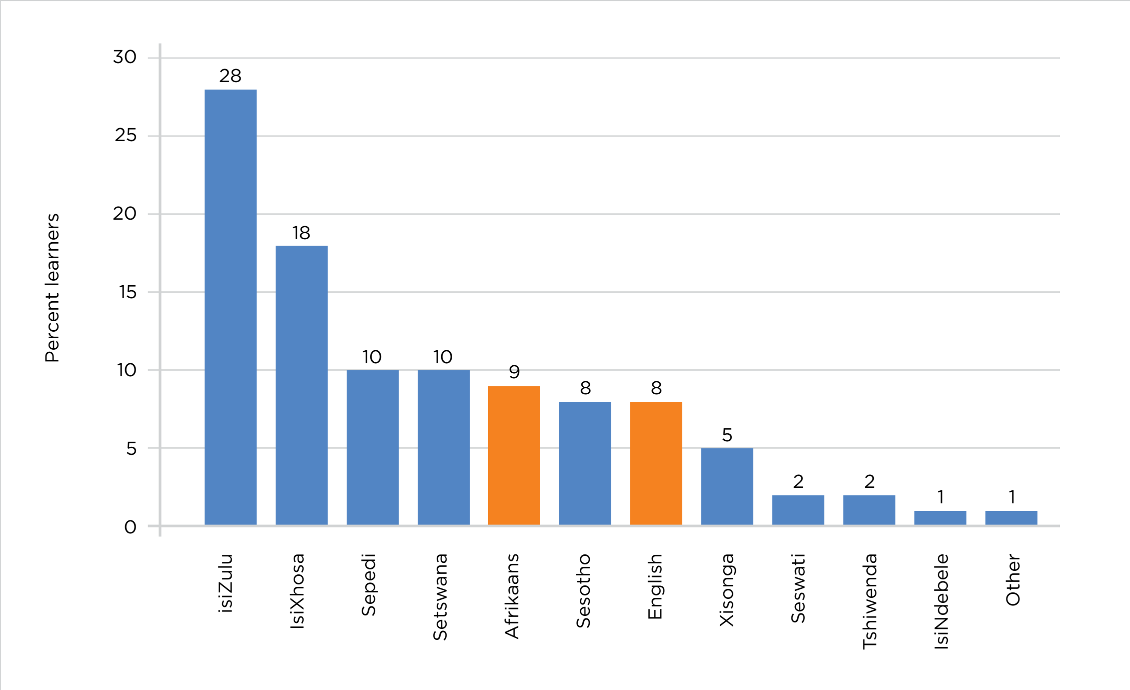
Learners' linguistic characteristics and achievement

We report on (i) the language that learners spoke most often at home and (ii) the extent to which they spoke the language of the test at home, and the relationship with mathematics and science achievement.

Learners' home language

South Africa is a linguistically diverse country, with 11 official languages enshrined in the Constitution. Figure 29 presents the language most commonly spoken at home as reported by learners. isiZulu was the most common language spoken at home (28%), followed by isiXhosa (18%). The TIMSS assessments were administered in the South African Language of Learning and Teaching (LoLT) in each school. This was either English or Afrikaans, the languages that were spoken by eight percent and nine percent of learners at home, respectively.

Figure 29: Home languages of learners (TIMSS 2019)



Source: TIMSS 2019 South African Grade 9 dataset.

Note: Afrikaans and English are highlighted as they are the languages in which TIMSS 2019 was administered.

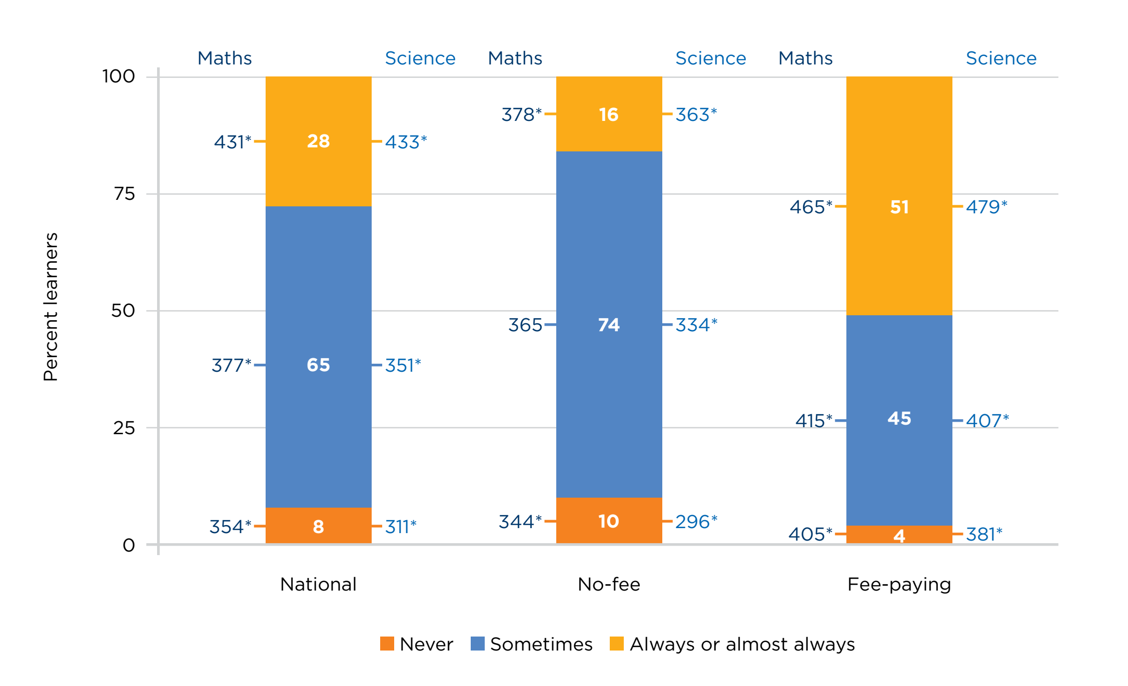
Learners' proficiency in the language of the test and association with achievement

Language proficiency has been shown to be related to learning and achievement scores (Howie, 2003; Prinsloo, Rogers & Harvey, 2018). Language proficiency in the language of teaching, learning, and assessment provides access to the learning process. Learners reported the extent to which the language of the test was spoken at home (Figure 30). This response was used here as a proxy for the ability of learners to read and understand the TIMSS items.

Twenty-eight percent of learners reported that they 'always or almost always' spoke the language of the test at home; 65 percent 'sometimes' spoke it, and eight percent 'never' spoke the language of the test at home. One in six learners in no-fee schools, and one in two learners in fee-paying schools frequently spoke the language of the test at home. Learners who 'frequently' spoke the language of the test at home achieved significantly higher mathematics and science scores than those who 'never' spoke the language of the test at home (431 versus 354 for mathematics, and 433 versus 311 for science).

This analysis confirms previous studies that found that learners who frequently spoke the language of instruction, were regularly exposed to this language, and used the language outside of the school, were at an advantage.

Figure 30: Percentage of learners speaking the language of the test at home, and mathematics and science achievement, by school type (TIMSS 2019)



* The achievement difference is statistically significant when compared to the other categories in the figure.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Age of learners and achievement

The average age of South African learners in the TIMSS 2019 cohort, at the time of administration, was 15.5 years. Girls were younger than boys, at 15.3 years and 15.8 years, respectively. The average age of South African Grade 9 learners was over a year older than most countries participating in TIMSS, at Grade 8.

The average age of learners may, in some cases, signal the extent of grade repetition. The General Household Survey, acknowledging the under-reporting of grade repetition, estimates that 11.3 percent of Grade 9 learners would have repeated at least one grade in their schooling career (StatsSA, 2018).

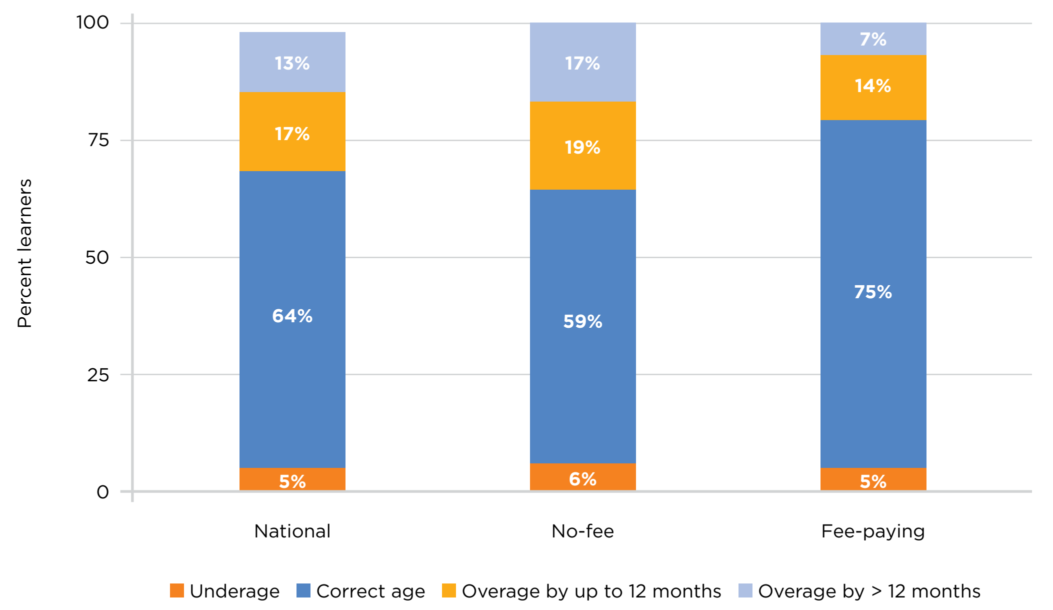
We investigated the extent of overaged learners in South Africa. Grade 9 learners who started school at the correct age, and who progressed through school without repeating a grade or other interruptions, would have been aged between 14.2 and 16.0 years at the time of the 2019 TIMSS administration. We then categorised other learners as either underage or overage[21]. Figure 31 reports the age distribution of learners for South Africa, and for no-fee and fee-paying schools.

Nationally, 30 percent of Grade 9 learners were overage in 2019. This pattern was different in no-fee and fee-paying schools, where 36 percent and 21 percent of learners, respectively, were overage. Learners could be overage due to starting school late, dropping in and out of school, or repeating a grade.

Next, we explored the relationship between learners' age and achievement scores (Figure 31). Learners who were the correct age for the grade (probably no grade repetition) achieved significantly higher mathematics and science scores than those who were overage. The oldest learners achieved the lowest scores. This does suggest that previous episodes of grade repetition had done little to enhance learning and improve performance.

21 Underage learners were younger than 14.17 years; correct age learners were aged 14.18 to 15.99 years; overage by up to 12 months were learners aged 16.0 to 16.99 years; overage by more than 12 months were learners aged 17.0 years or above.

Figure 31: Age distribution of the cohort by school type (TIMSS 2019)



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Next, we explored the relationship between learners' age and achievement scores (Table 10). Learners who were the correct age for the grade (probably no grade repetition) achieved significantly higher mathematics and science scores than those who were overage (409 versus 334 for mathematics and 398 versus 289 for science). The oldest learners achieved the lowest scores. This does suggest that previous episodes of grade repetition had done little to enhance learning and improve performance.

It is worth noting that the percentage of learners at the correct age for the grade increased from 53 percent in TIMSS 2011 to 64 percent in TIMSS 2019. This could be due to school enrolment and retention policies improving and the extent of grade repetition decreasing.

Table 10: Learner achievement in mathematics and science by age distribution (TIMSS 2019)

Age category			Mathematics Mean (SE)	Science Mean (SE)
Underage	On track	5%	400 (5.4)	385 (7.2)
Correct age	On track	64%	409 (2.3)	398 (3.2)
Overage by up to 12 months	+ 1 year	17%	358 (2.4)	328 (3.1)
Overage by > 12 months	+ 2 years	13%	334 (2.8)	289 (3.9)
National average			**389 (2.3)**	**370 (3.1)**

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

5.2. HOME ENVIRONMENT OF LEARNERS

The extant literature confirms that the SES of the home is related to educational achievement, and future educational and labour market trajectories (See Chapter 1). In the context of high levels of income inequality, as in South Africa, personal conditions such as where one lives and learns influence educational outcomes. TIMSS 2019 asked learners about the assets and educational resources available in their homes. This allows us to explore the relationship between learners' socioeconomic environments and their achievement on the TIMSS mathematics and science assessments.

Availability of home assets

Household assets influence the extent of opportunities that a household has, and the differentiation across households is a signal of the inequality of opportunities. Figure 32 reports the percentage of learners who had what we categorised as basic, educational or digital assets in their homes in 2019. These assets are used as a proxy measure of a home environment that can effectively support learning. Having these assets was positively associated with higher mathematics and science achievement. We report on the availability of these assets, firstly at the national level, and then for learners in public no-fee, public fee-paying and independent schools.

We expect most homes to be equipped with basic assets such as electricity, running tap water, water flush toilets and hot running water from a geyser. Access to these basic amenities has been shown to facilitate learners successfully participating in learning. According to learner reports, over 90 percent of South African households had access to electricity in 2019, but it is disconcerting that only three-quarters of homes had access to running tap water, 60 percent of households had water flush toilets, and only 35 percent had hot running water from a geyser[22]. There was a significant difference in the availability of these basic assets in the homes of learners attending less affluent (no-fee) and more affluent (fee-paying and independent) schools, making clear the inequality in the availability of resources that facilitate learning. These unequal home conditions predict the future educational achievement and trajectories for learners.

Learners' home educational and social capital can be gleaned from the education level of their parents, the extent to which the language of the test was spoken at home, and the number of books at home. Parental education is a signal of the wealth and social capital of the household and has strong positive links with learner achievement. Thirty-eight percent of learners reported that at least one parent had a post-secondary education[23]. Twenty-eight percent of learners always or almost always spoke the language of the test at home, and thus had better linguistic access to the assessment; and 18 percent of learners reported having more than 25 books in the home. While the availability of educational assets was low for the majority of learners, the absence of these assets was much higher for learners in no-fee schools, which negatively affected learning outcomes. There was a statistically significant difference in the availability of assets among the three school types.

In the era of technological and digital advancement, computers or tablets and Internet connectivity at home have become essential items for learning. Half of the learners (48%) reported coming from homes that had a computer or tablet, and four in ten (41%) came from households that had an Internet connection[24]. Learners in no-fee schools had less access to these resources, with only 38 percent reporting having a computer and 32 percent having an Internet connection at home (this may be over-reported). Just over three-quarters of learners reported having their own cell phones, which could be considered a means by which schools could connect with learners. There was a statistically significant difference in the availability of assets among the three school types.

22 There is a high percentage of missing values on this variable in the TIMSS 2019 dataset.

23 The TIMSS data on availability of water flush toilets and hot water geyser corroborates with data in the General Household Survey (GHS) 2019 report (StatsSA, 2020a).

24 When compared with GHS 2019 figures, learners may have over-reported the availability of computers and Internet connections at home. The GHS 2019 reports that 23 percent of households have a computer and nine percent have access to Internet at home (StatsSA, 2020a). For Internet at home, learners may have included Internet on cell phones. In 2019, Internet penetration was 54 percent and 170 percent mobile contracts (Digital 2019: South Africa https://datareportal.com/reports/digital-2019-south-africa).

Figure 32: Percentage of learners having basic, educational, and digital assets at home (TIMSS 2019)

Asset type	Possession	National	No-fee paying	Fee-paying	Independent
Basic	Electricity*	93	91	97	99
	Running tap water*	73	65	89	94
	Waterflush toilets*	60	44	90	96
	Hot running water from a geyser*	35	20	61	78
Educational	Parents have post-secondary education*	38	34	46	63
	Always/almost always speak test language at home*	28	16	51	53
	Over 25 books at home*	18	13	26	41
Digital	Own cell phone*	77	74	83	90
	Computer or tablet*	48	38	67	83
	Internet connection*	41	32	57	74

* Statistically significant difference of percentage of learners with availability of assets between no-fee and fee paying schools.

Source: Author's own calculations from TIMSS 2019 dataset.

Trends in availability of home assets from 2003 to 2019

Although the availability of basic assets was still low in 2019, this had improved over time (Figure 33). From 2003 to 2019, the percentage of learners reporting the availability of basic assets in their homes increased by 12 percent for electricity, seven percent for running tap water and 11 percent for water flush toilets. However, one would have expected that over this 16-year period, access to running tap water and water flush toilets would have improved more.

The changes in availability of educational capital in the home also improved during this time. The percentage of learners who reported frequently speaking the language of the test at home increased by three percent from 2003 to 2019[25]. Learner reports of the highest level of parental education were poor, with a high percentage of missing values. According to learner reports in TIMSS 2003, 24 percent of learners had at least one parent with a post-secondary education. This increased to 38 percent in 2019.

We complemented the TIMSS learner responses with StatsSA GHS data to examine the changes in education levels of the adult population. According to the GHS, the population aged 20 years and older who reported they had attained a grade 12 certificate was 22 percent in 2003, 28 percent in 2011 and 31 percent in 2019 (StatsSA, 2020a). Clearly, the education level across households increased from 2003 to 2011, thus improving home social capital, which in turn should contribute to higher educational achievement.

25 While speaking the language of the test at home is a useful proxy for proficiency in the test language, we caution that there may not necessarily be a one-to-one correspondence.

Figure 33: Trend in availability of home assets from 2003 to 2019

Asset type	Possession	2003	2011	2019
Basic	Electricity	81	87	93
	Running tap water	66	72	73
	Waterflush toilets	49		60
	Hot running water from a geyser			35
Educational	Parents have post-secondary education	24	37	38
	Always/almost always speak test language at home	25	26	28
	Over 25 books at home	23	23	18
Digital	Own cell phone		79	77
	Computer or tablet	33	36	48
	Internet connection		32	41

Source: Author's own calculation from TIMSS South African Grade 9 dataset.

Home asset scale

We used principal component analysis to create the *Home Asset Scale*[26] Cut-scores divided the scale scores into three categories: High (have at least four assets, including an Internet connection at home), medium (at least four assets but no Internet connection, or any three assets), and low (fewer than three assets). This *Home Asset Index* is used as a proxy of the SES of the learner.

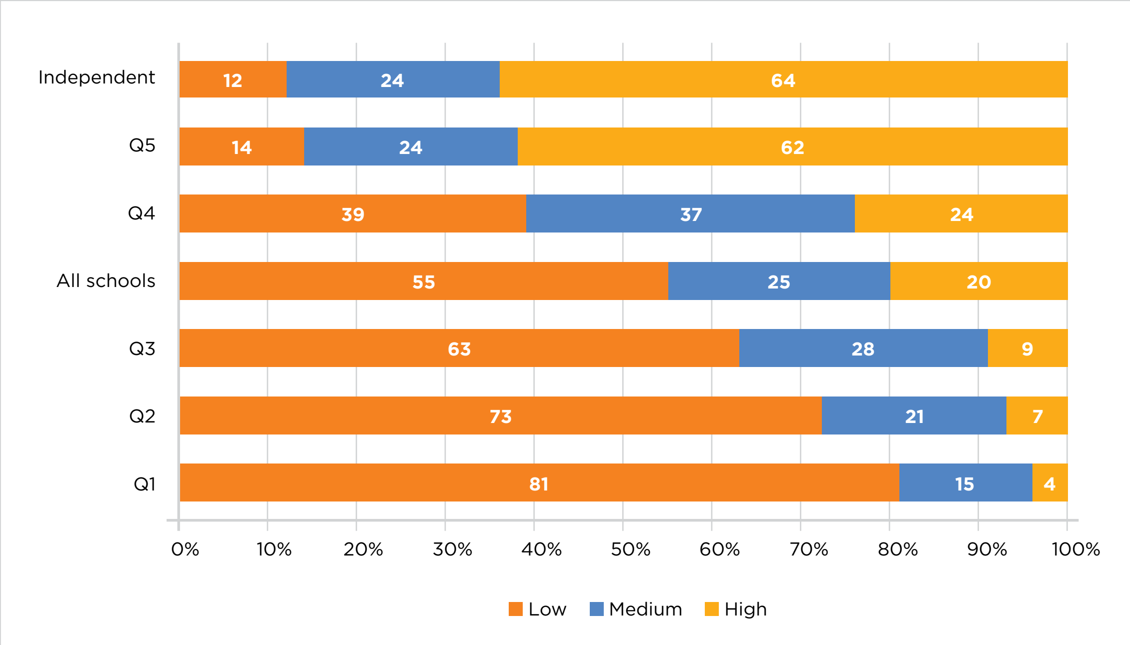
According to the *Home Asset Scale*, 20 percent of South African households were categorised as high SES, 25 percent as medium SES, and 55 percent as low SES. This indicator corroborates the World Bank (2018) categorisation for South Africa, where 49 percent of the population were characterised as chronic poor, 13 percent as transient poor, 14 percent vulnerable, 20 percent middle class and four percent elite.

Profile of schools by learners' home asset status

In order to form a picture of the distribution of learners by SES across schools, we plotted the graph shown in Figure 34. The majority of learners in school Quintile 1, 2 and 3 came from low SES homes. A quarter of learners in school quintile 4 were from high SES homes, and the others were split almost equally among low and medium SES homes. The SES profiles of learners in school Quintile 5 and independent schools were fairly similar, with just over 60 percent of learners coming from high SES homes. This graph illustrates the reproduction of society, where the inequalities that begin at home are continued to schools having less than optimal teaching and learning conditions.

26 The scale was based on the availability of the following assets (i) running tap water, (ii) flush toilet in the home, (iii) hot running water, (iv) more than 25 books in the home, and (v) Internet connection to the home.

Figure 34: Percentage of learners by socioeconomic status in school quintiles



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Relationship between home assets and achievement

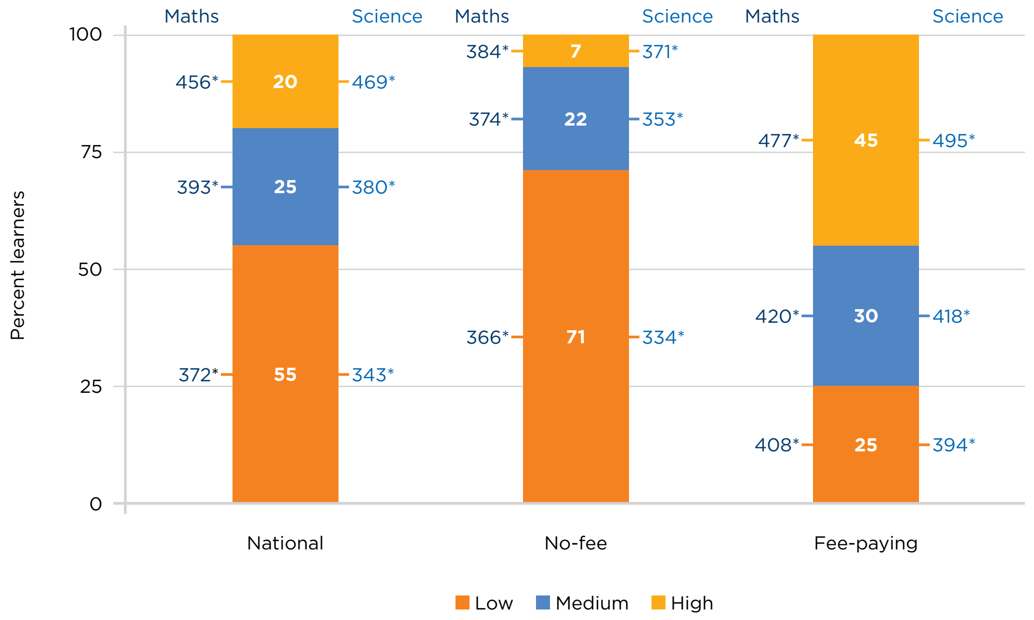
We examined the relationship between the *Home Asset Scale* and mathematics and science achievement. Figure 35 shows that, as expected, both learners' mathematics and science achievement had a positive relationship with the availability of home assets. Achievement was highest for learners from homes with the most assets for both mathematics (456) and science (469), and lowest for those learners from homes with the least assets (372 for mathematics and 343 for science).

We then disaggregated school type into categories of no-fee and fee-paying schools, and examined the relationship between the *Home Asset Scale*, and mathematics and science achievement. In no-fee schools, seven percent of learners were classified as coming from high SES homes, 22 percent as medium SES, and 71 percent as low SES. The corresponding figures in fee-paying schools were 45 percent (high), 30 percent (medium) and 25 percent (low).

As at the national level, in both no-fee and fee-paying schools learners categorised as coming from homes with high SES achieved significantly higher mathematics and science scores than learners from homes with medium SES, who in turn achieved significantly higher scores than those from homes with low SES. This clearly shows the significant relationship between mathematics and science achievement, and assets available in the home.

These results confirm one of the most enduring findings in the social sciences literature: that the circumstance you were born into is the biggest predictor of where you end up.

Figure 35: Mathematics and science achievement by socioeconomic status of the home (TIMSS 2019)



* Statistically significant achievement difference between categories.

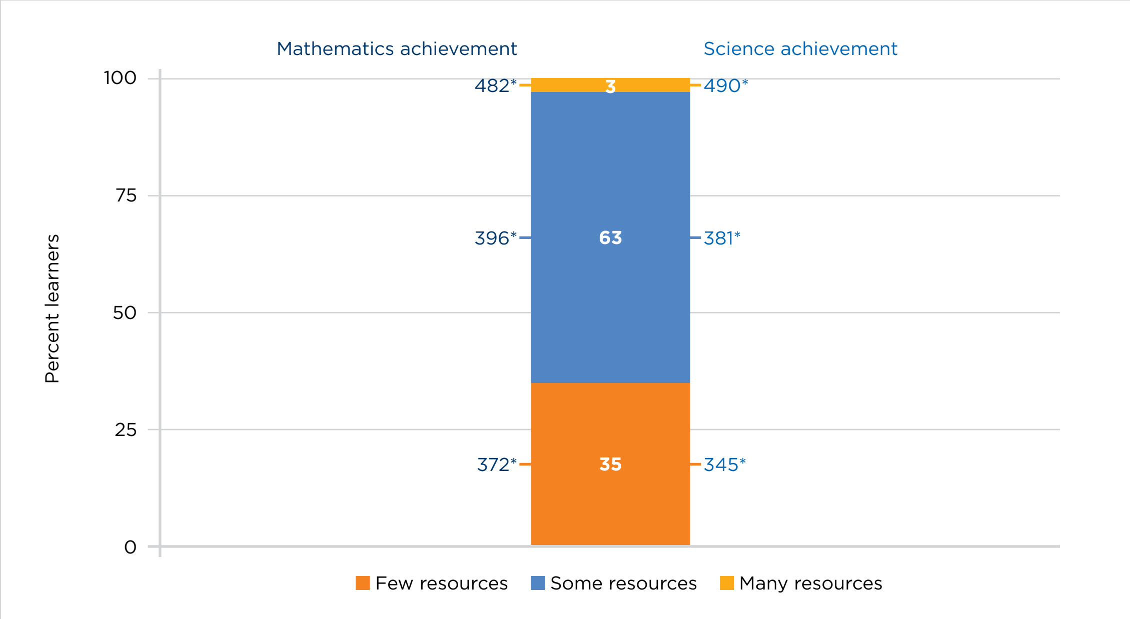
Source: Author's own calculation from TIMSS 2019 South African Grade 9 dataset.

Home educational resources, and mathematics and science achievement

In addition to the availability of home assets, we explored the role of home educational resources in mathematics and science achievement. TIMSS constructed a *Home Educational Resources (HER) Scale* from learner reports[27]. Figure 36 reports the proportion of learners with different levels of home educational resources, and the corresponding mathematics and science achievement. According to this scale, only three percent of Grade 9 South African learners had 'many' home educational resources (compared to 14 percent internationally). Like with the *Home Assets Scale*, there was a significant positive association between the availability of home educational resources and achievement, with learners from homes with many educational resources achieving higher than those from homes with few resources (482 versus 372 for mathematics, and 490 versus 345 for science).

27 The HER scale summarises 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. See TIMSS 2019 International Results in Mathematics and Science Report for a description of the HER Scale (https://timss2019.org/reports/download-center/; Page 290).

Figure 36: Relationship between Home Educational Resources Scale and mathematics and science achievement (TIMSS 2019)



Source: TIMSS 2019 South African Grade 9 dataset.

Home support for learning

Homework has been found to positively influence achievement and improve the development of key learning skills (Pfeiffer, 2018). Giving learners homework to do after school has benefits such as refreshing their knowledge and skills. Studies have found that parents helping with homework is also beneficial (e.g. Eschaune, Ndiku & Sang, 2015).

TIMSS assessed parental support for homework by asking learners if their parents made sure that they set aside time for their homework and checked whether they had completed their homework. The majority of learners reported that their parents checked at least once a week that they set aside time for their schoolwork (84%) and that their homework was completed (77%). The majority of parents, in both low and high resourced contexts, provided support to their children to ensure that time was spent on homework and that homework was completed.

Barriers to providing support for learning

The ability of parents to help with homework can, however, be limited by their education levels (only 38 percent of learners reported that one of their parents had a post-secondary education), not speaking the language of the test, and the complex nature of the subject matter. TIMSS 2019 asked learners to indicate the extent to which their parents struggled with (i) the language in which their homework was provided and (ii) the difficulty level of the homework content.

Close to two-thirds of learners reported that their parents were at least sometimes unable to assist them with homework because it was in a language they did not understand (63%), or that the subject matter was at least sometimes so difficult that their parents struggled with the content (65%) (Table 11 and Table 12). Learners who reported their parents hardly ever struggled with the homework language or the complexity of the subject matter achieved significantly higher mathematics and science scores than learners whose parents frequently or sometimes struggled. These findings reinforce the literature of the relationship between having more home educational capital and higher achievement scores.

Table 11: Relationship between parents supporting learners' homework and mathematics achievement (TIMSS 2019)

	Hardly Ever		Sometimes		Frequently	
	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)
Parents struggle with language of homework	38	425* (2.3)	43	376* (2.2)	20	358* (2.9)
Parents struggle with content of homework	35	408* (2.4)	49	389* (2.3)	16	363* (2.9)

Source: TIMSS 2019 South African Grade 9 dataset.

Table 12: Relationship between parents supporting learners' homework and science achievement (TIMSS 2019)

	Hardly Ever		Sometimes		Frequently	
	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)
Parents struggle with language of homework	38	422* (3.0)	43	350* (2.9)	20	324* (4.2)
Parents struggle with content of homework	35	398* (3.1)	49	369* (3.3)	16	331* (3.8)

Source: TIMSS 2019 South African Grade 9 dataset.

The infographic that follows presents a summary of individual learners' characteristics and aspects of their home environments, and how these are associated with their mathematics and science achievement.

5.3. SUMMARY: LEARNER CHARACTERISTICS AND THEIR HOME ENVIRONMENTS

Learners' gender and mathematics and science achievement

From the bivariate analysis (refer to Reader's Guide), we observed a statistically significant gender achievement difference with girls outperforming boys in mathematics and science. We observed the same statistically significant achievement difference between girls and boys in no-fee schools, but the difference was not significant in fee-paying schools.

Learners' language proficiency and achievement

Twenty-eight percent of South African learners had high proficiency in the language of the test. When disaggregated by fee-status of schools, one-sixth of learners (16%) in no-fee schools and half the learners (51%) in fee-paying schools always or almost always spoke the language of the test at home.

Learners who 'frequently' spoke the language of the test at home achieved significantly higher mathematics and science scores than those who 'never' spoke the language of the test at home. This analysis confirms previous studies that found that learners who frequently spoke the language of instruction, were regularly exposed to it, and used the language outside of the school, were at an advantage.

Age of learners and achievement

The average age of South African Grade 9 learners was over a year older than most countries who participated in TIMSS at Grade 8. Nationally, 30 percent of Grade 9 learners were overage in 2019 (36 percent of learners in no-fee schools and 21 percent in fee-paying schools). It is worth noting that the percentage of learners who were overage for the grade decreased from 45 percent in TIMSS 2011 to 30 percent in TIMSS 2019.

Learners who are overage are more likely to have repeated earlier grades. Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage. This does suggest that previous episodes of grade repetition had done little to enhance learning and improve performance.

Home assets, Home Asset Scale and achievement

Learners start from unequal home conditions, leading to inequalities in educational opportunities and outcomes. Although the availability of assets increased since 2003, learners in no-fee schools still had significantly fewer basic, educational and digital assets than learners in fee-paying schools.

According to the *Home Asset Scale*, 20 percent of South African households were categorised as high SES, 25 percent as medium SES, and 55 percent as low SES. In no-fee schools, seven percent of learners were classified as coming from high SES homes, 22 percent as medium SES, and 71 percent as low SES. The corresponding figures in fee-paying schools were 45 percent (high), 30 percent (medium) and 25 percent (low).

Learners from homes with higher levels of assets and resources achieved significantly higher mathematics and science scores than learners from homes with less assets and resources. The results from TIMSS confirmed one of the most enduring findings: the circumstances you are born into is the biggest predictor of where you end up.

Home support for learning mathematics and science

Parents helping with homework is beneficial for learning, but the ability of parents to help with homework can be limited by their education levels. Two-thirds of learners reported that their parents were at least sometimes unable to assist them with homework because it was in a language they did not understand, or that the subject matter was so difficult that their parents struggled with the content.

Learners who reported that their parents hardly ever struggled with the language of the homework or the complexity of the subject matter achieved significantly higher mathematics and science scores than learners whose parents frequently or sometimes struggled. These findings reinforce the literature on the relationship between having more home educational capital and higher achievement scores.

The next chapter discusses learners' attitudes to mathematics and science and the relationship with achievement. We explore whether learners like the subjects, place value on them, and are confident in their mathematics and science abilities.

CHAPTER SIX

LEARNER ATTITUDES TOWARDS MATHEMATICS AND SCIENCE

There is an emerging interest around how non-cognitive factors, such as personality, attitudes, and social and emotional traits are related to achievement (Heckman, 2006; Cunha et al, 2010). This chapter explores how the non-cognitive factor of learner attitudes is associated with mathematics and science achievement.

The extant literature shows that learners with positive attitudes toward mathematics and science have higher average achievement in those subjects. While positive attitudes and higher mathematics and science achievements go hand in hand, it should be understood that the relationship is bidirectional, with attitudes and achievement mutually reinforcing each other.

TIMSS has been measuring learner attitudes toward mathematics and science since the 1995 cycle. TIMSS 2019 measured learner attitudes towards mathematics and science through three scales: *Learners Like Learning Mathematics, Learners Value Mathematics,* and *Learners Confident in Mathematics*, with equivalent scales in science measuring similar constructs. The South African Curriculum and Assessment Policy Statements also embrace the role of the non-cognitive outcomes for mathematics and science (Annexure 3).

6.1. LEARNERS LIKE LEARNING MATHEMATICS AND SCIENCE

The *Learners Like Learning Mathematics* and *Learners Like Learning Science* scales measure learners' intrinsic motivation to learn the subjects. Intrinsic motivation refers to undertaking an action or task for its inherent satisfaction rather than due to an external pressure or reward (Ryan & Deci, 2000). Learners who are intrinsically motivated to learn mathematics or science find the subject to be interesting and enjoyable. Previous TIMSS data have shown a strong relationship between the liking scales and learner achievement. Table 13 reports the learners' agreement (agreeing a lot) with statements related to their liking learning mathematics and science.

Overall, around half of the learners expressed strongly positive attitudes towards learning mathematics. A slightly higher percentage expressed strongly positive attitudes towards learning science.

Table 13: Percentage of learners who agreed 'a lot' with statements about liking learning mathematics and science

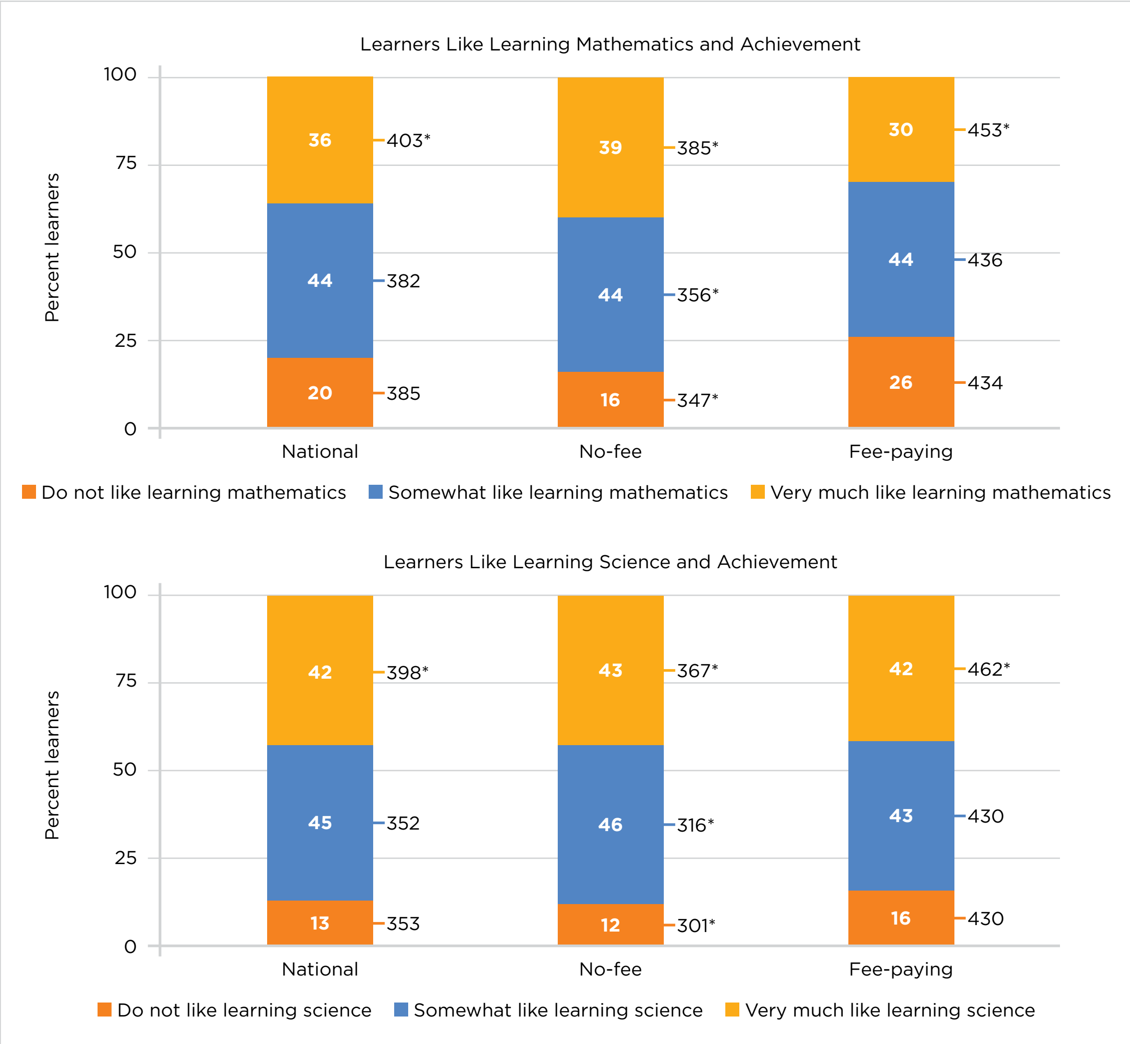
Learning mathematics	Percent learners Agree a lot	Learning science	Percent learners Agree a lot
I learn many interesting things in mathematics	53	I learn many interesting things in science	62
I enjoy learning mathematics	52	I enjoy learning science	55
I like mathematics	49	I like science	54
I look forward to mathematics lessons	45	I like to conduct science experiments	52
I like to solve mathematics problems	40	Science teaches me how things in the world work	67
I like any schoolwork that involves numbers	39	I look forward to learning science in school	52
Mathematics is one of my favourite subjects	36	Science is one of my favourite subjects	43
I wish I did not have to study mathematics	14	I wish I did not have to study science	12
Mathematics is boring	9	Science is boring	9

Source: TIMSS 2019 South African Grade 9 dataset.

Learners were scored according to the nine responses on the *Learners Like Learning Mathematics/Science* scales. The scale was then divided into three categories: 1) *very much like learning* mathematics/science, 2) *somewhat like learning* mathematics/science, and 3) *do not like learning* mathematics/science[28]. On this scale, 36 percent of South African learners reported that they 'very much liked learning mathematics', placing the country in fourth place out of the set of participating countries in terms of positive attitudes. The corresponding international average was 20 percent. Forty-two percent of South African learners 'very much liked learning science', placing the country in the top third of all participating countries. The corresponding international average was 35 percent.

Next, we examined the association between the *Learners Like Learning Mathematics/Science* scales, and mathematics and science achievement (Figure 37). Learners at the national level, and in fee-paying schools, who 'very much liked learning' mathematics and science achieved significantly higher mathematics and science scores than learners who 'somewhat' or 'did not like learning' mathematics or science. In no-fee schools this relationship was more distinct, and learners who 'very much liked learning' mathematics and science significantly outscored those who 'somewhat liked learning' mathematics or science, who in turn outscored those who 'did not like learning' mathematics or science.

Figure 37: Learners like learning mathematics or science and achievement



* Statistically significant achievement differences between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

28 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description of the Learners Like Learning Mathematics Scale (Page 428) and Learners Like Learning Science Scale (Page 431).

6.2. LEARNERS VALUE MATHEMATICS AND SCIENCE

TIMSS also measures extrinsic motivation through the Learners Value Mathematics and Learners Value Science scales. Extrinsic motivation refers to the drive that comes from attaining a separable outcome, such as praise, career success, money, and other incentives (Ryan & Deci, 2000). Table 14 records learners' responses of 'agreeing a lot' to statements related to their valuing mathematics or science.

While over two-thirds of learners recognised the value of mathematics for future studies, for getting a job and to get ahead in the world, only 42 percent expressed a desire to get a job that involved using mathematics. Learners' response to the value of science was slightly less than that for mathematics.

Table 14: Percentage of learners who agreed 'a lot' with statements regarding their valuing mathematics and science

Valuing mathematics	Percent learners Agree a lot	Valuing science	Percent learners Agree a lot
It is important to do well in mathematics	81	It is important to do well in science	65
I need to do well in mathematics to get into the university of my choice	80	I need to do well in science to get into the university of my choice	60
I think learning mathematics will help me in my daily life	77	I think learning science will help me in my daily life	69
I need to do well in mathematics to get the job I want	77	I need to do well in science to get the job I want	60
Learning mathematics will give me more job opportunities when I am an adult	75	Learning science will give me more job opportunities when I am an adult	59
My parents think that it is important that I do well in mathematics	71	My parents think that it is important that I do well in science	52
It is important to learn about mathematics to get ahead in the world	67	It is important to learn about science to get ahead in the world	58
I need mathematics to learn other school subjects	53	I need science to learn other school subjects	49
I would like a job that involves using mathematics	42	I would like a job that involves using science	51

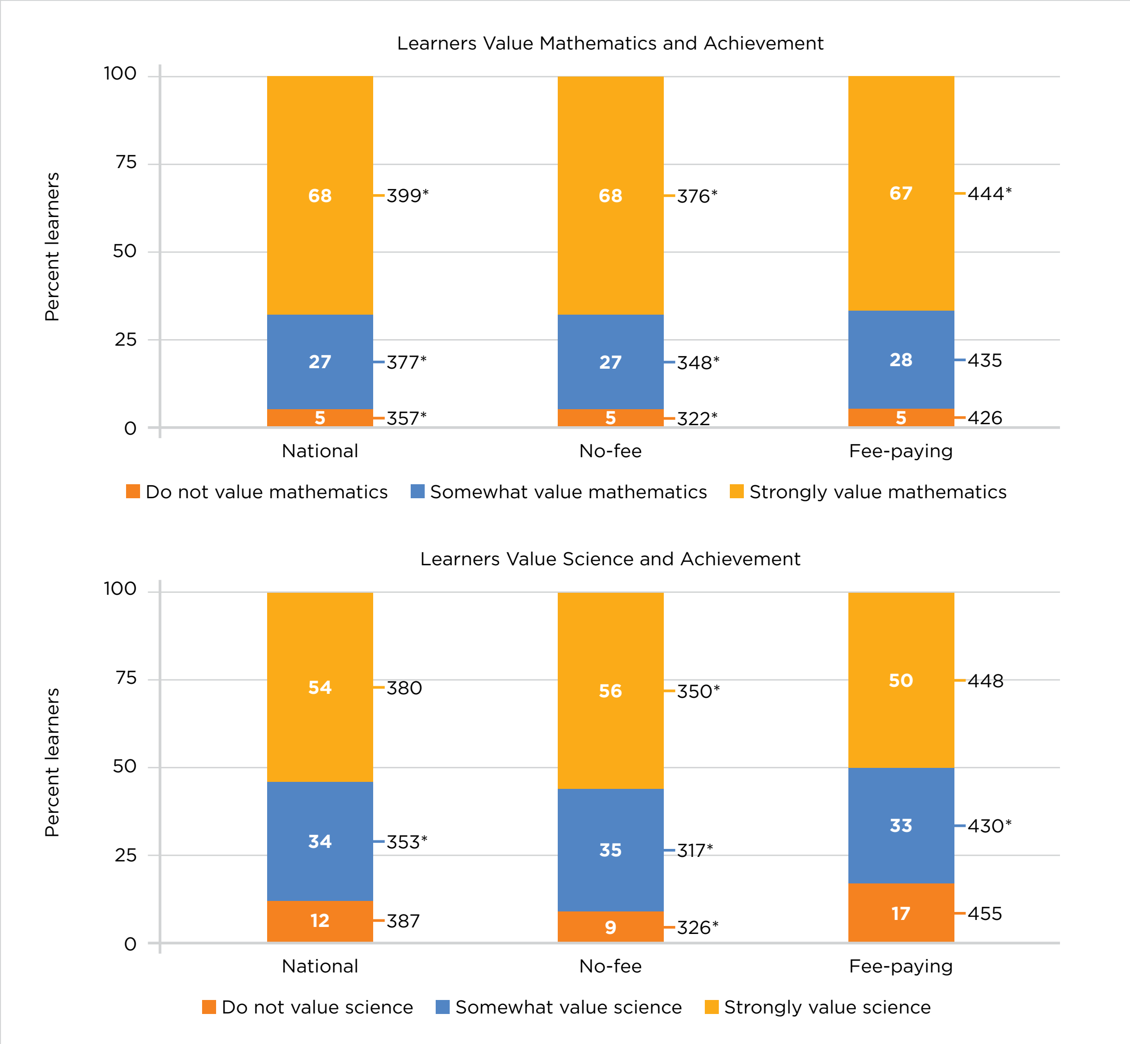
Source: TIMSS 2019 South African Grade 9 dataset.

Learners were scored according to the nine responses on the *Learners Value Mathematics/Science* scales. The scale was then divided into three categories: 1) *strongly value* mathematics/science, 2) *somewhat value* mathematics/science, and 3) *do not value* mathematics/science[29]. On this scale, when compared to other participating countries, South African learners valued mathematics the most, with just over two-thirds (68%) of learners strongly valuing mathematics. The corresponding international average was 37 percent. Just over half (54%) of South African learners 'strongly valued science', placing it at the top end of countries who valued science strongly. The corresponding international average was 36 percent.

Next, we examined the association between the *Learners Value Mathematics/Science* scales, and mathematics and science achievement (Figure 38). Learners who strongly valued mathematics achieved significantly higher scores than those who valued mathematics less. The pattern was less linear for science, with learners who 'strongly valued' or 'did not value' science both achieving science scores that are not significantly different from each other.

29 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/)for a description of the Learners Value Mathematics Scale (Page 444) and Learners Value Science Scale (Page 446).

Figure 38: Learners valuing mathematics or science and achievement



* Statistically significant achievement scores between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

6.3. LEARNERS CONFIDENT IN MATHEMATICS AND SCIENCE

Learners tend to have distinct views of their ability for success in different subjects, and their self-appraisal is often based on their past experiences and how they see themselves compared with their peers (Marsh & Craven, 2006). TIMSS measures subject-specific self-concept through the *Learners Confident*[30] *in Mathematics* and *Learners Confident in Science* scales. The results from six previous TIMSS cycles have shown a strong relationship between learners' academic self-concept and their achievement. South African analyses of the relationship between self-concept, and mathematics and science achievement, confirmed the strong relationship (Juan, Reddy & Hannan, 2014; Juan, Hannan & Namome, 2018).

Table 15 records the percentage of learners 'agreeing a lot' with statements related to their confidence in mathematics or science. Overall, learners were more cautious and circumspect in rating their confidence in learning mathematics and science, than they were about their liking and valuing mathematics and science. About a quarter of mathematics learners and a third of science learners were confident in their mastery of the subject matter.

30 Some authors, such as Bandura (1977) refers to this construct as self-efficacy. Self-efficacy is a person's belief in their ability to succeed in a particular situation or cognitive strength. The elements of self-efficacy are mastery experiences, social persuasion, vicarious experiences and emotional state.

One in four mathematics learners, compared to one in eight science learners, reported that the respective subjects (mathematics and science) were more difficult for them than for many of their classmates. One in five learners indicated that they had the approval of their educator in relation to their mathematics and science abilities. A quarter of learners felt high anxiety levels about learning mathematics and science.

Table 15: Percentage of learners who agreed 'a lot' with statements regarding their confidence in mathematics and science

Confidence in mathematics	Percent learners Agree a lot	Confidence in science	Percent learners Agree a lot
Mastery experience			
I learn things quickly in mathematics	27	I learn things quickly in science	39
I usually do well in mathematics	26	I usually do well in science	38
I am good at working out difficult mathematics problems	20	I am good at working out difficult science problems	30
Mathematics is not one of my strengths	25	Science is not one of my strengths	17
Mathematics is harder for me than any other subject	30	Science is harder for me than any other subject	15
Vicarious experience			
Mathematics is more difficult for me than for many of my classmates	23	Science is more difficult for me than for many of my classmates	13
Social persuasion			
My educator tells me I am good at mathematics	17	My educator tells me I am good at science	22
Emotional/physiological state			
Mathematics makes me nervous	28	-	-
Mathematics makes me confused	25	Science makes me confused	15

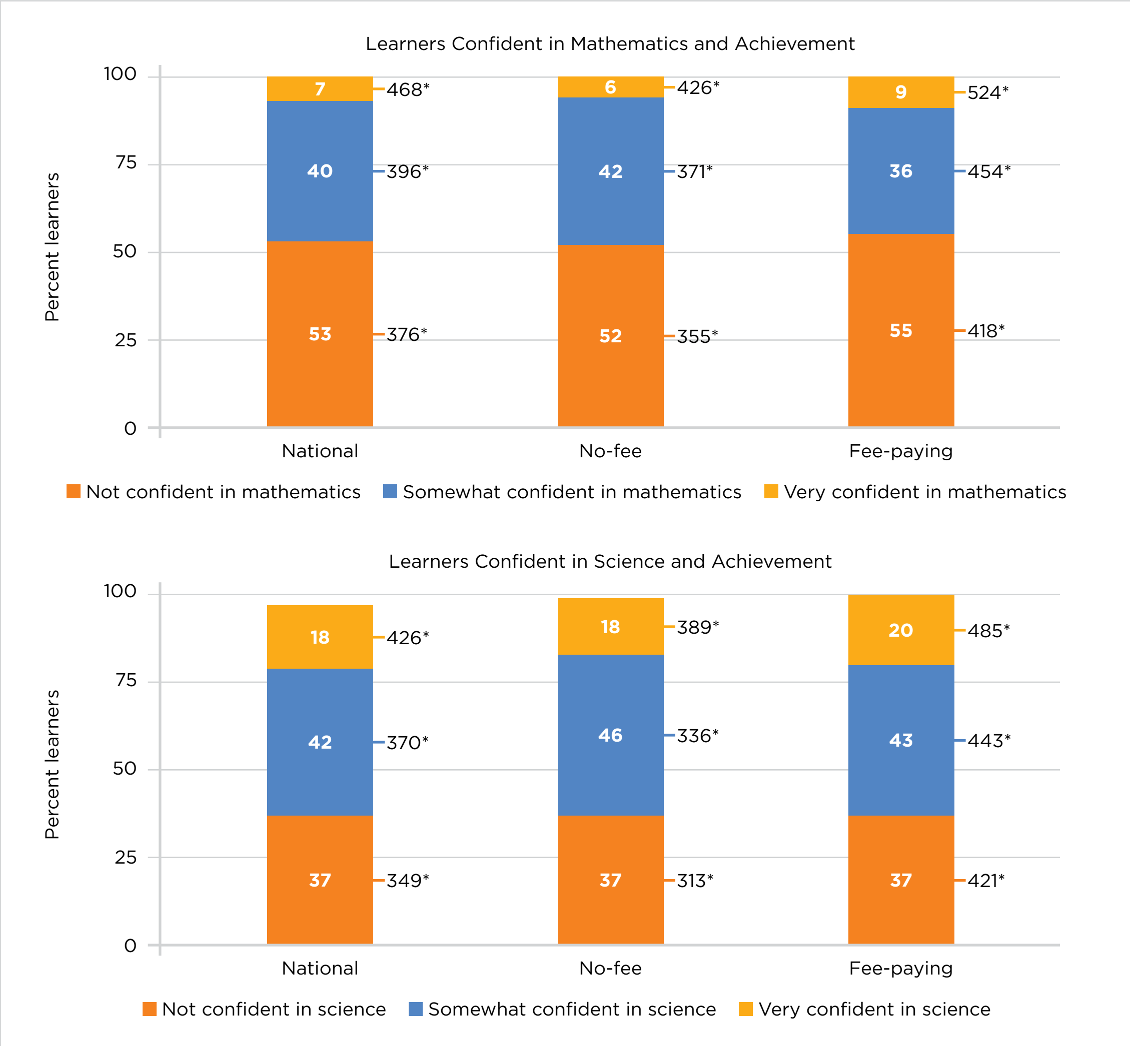
Source: TIMSS 2019 South African Grade 9 dataset.

Learners were scored according to the nine statements in the *Learners Confident in Mathematics* scale, and eight statements in the *Learners Confident in Science* scale. Each scale was then divided into three categories: 1) *very confident* in mathematics/science, 2) *somewhat confident* in mathematics/science, and 3) *not confident* in mathematics/science[31]. On this scale, seven percent of South African learners were categorised as 'very confident' in mathematics, with the corresponding international average at 15 percent. Eighteen percent of learners were very confident in science, in comparison with 23 percent internationally.

Next, we examined the association between the Learners Confident in Mathematics/Science scales, and mathematics and science achievement. For mathematics and science, at the national level, as well as in no-fee and fee-paying schools, there was a significant positive association between the level of confidence in mathematics and science, and the corresponding achievement (Figure 39). This honest appraisal by learners of their mathematics and science abilities is a good starting point to encourage learners' efforts to improve their achievement scores.

31 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description of the Learners Confident in Mathematics Scale (Page 436) and Learners Confident in Science Scale (Page 439).

Figure 39: Learners confident in mathematics or science and achievement



* Statistically significant achievement scores between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

The following infographic provides a summary of Grade 9 learners' attitudes to mathematics and science, and how the various attitudinal aspects related to achievement.

6.4. SUMMARY: LEARNER ATTITUDES TOWARDS MATHEMATICS AND SCIENCE

Global attitudes to mathematics and science

Comparing the cross-country responses related to learner attitudes, we observed that learners in lower income and lower performing countries expressed more positive attitudes to mathematics and science than learners in high income countries with generally higher performing learners.

While positive attitudes, and high mathematics and science achievement, go hand in hand, it should be understood that the relationship is bidirectional, with attitudes and achievement mutually influencing each other.

Learners like learning mathematics and science

Thirty-six percent of mathematics learners and 42 percent of science learners reported that they very much liked learning mathematics and science. These attitudes were more positive than most other TIMSS participating countries.

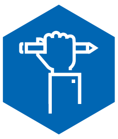
Learners who very much liked learning mathematics and science achieved significantly higher scores than those who only somewhat liked or did not like these subjects. In no-fee schools this relationship was more distinct, and learners who 'very much liked learning' mathematics and science significantly outscored those who 'somewhat liked learning' mathematics or science, who in turn outscored those who 'did not like learning' these subjects.

Learners value mathematics and science

Over two-thirds of mathematics learners, and around 60 percent of science learners, recognised the value of these subjects for their future studies, for getting a job and for getting ahead in the world. However, only 42 percent expressed a desire to get a job that involved using mathematics and 51 percent expressed a desire to get a job that involved using science.

Sixty-eight percent of South African learners reported that 'strongly valued mathematics' and 54 percent 'strongly valued science'. The corresponding international averages were 37 percent for mathematics and 36 percent for science.

Learners who valued mathematics highly achieved significantly higher scores than those who valued mathematics less. The pattern was less clear for science, with learners who strongly valued science or did not value science, achieving science scores that were not significantly different from each other.



Learners confident in mathematics and science

Overall, learners were more cautious and circumspect in rating their confidence in learning mathematics and science than they were about liking and valuing these subjects. Seven percent of South African learners reported they were very confident in mathematics, and 18 percent were very confident in science. The corresponding international averages were 15 percent and 23 percent, respectively.

For mathematics and science, at the national level, as well as in no-fee and fee-paying schools, there was a significant positive association between the level of confidence in mathematics and science, and the corresponding achievement. This honest appraisal by learners of their mathematics and science abilities is a good starting point to encourage learners' efforts to improve their achievement scores.

In Section E of this report, we examine various school and classroom factors, how these differ for learners in different school contexts, and how they are associated with learners' achievement.

SECTION E

SCHOOL AND CLASSROOM FACTORS RELATED TO ACHIEVEMENT

In addition to collecting achievement data, School and Educator Questionnaires were administered to the principal of each participating school, and to the mathematics and science educator of each class that took part in the TIMSS assessment. This section reports selected results from these contextual questionnaires and examines how the school and classroom environments in which learning occurs influence mathematics and science achievement.

TIMSS reports results by learner outcomes. The principal, mathematics and science educator responses are not representative of all South African principals or mathematics and science educators, as they were simply the principals and educators of a representative sample of learners assessed in TIMSS 2019. When information from educators and schools are reported, the learner remains the unit of analysis, that is the data shown are the percentage of learners whose educators or principals reported on a particular dimension.

This section consists of two chapters:

- Chapter Seven: *Schools as enabling learning environments* reports on school characteristics, principal demographics, as well as leadership and management support and school climate.
- Chapter Eight: *Classrooms: Educators, Resources and Instructional Practices* reports on educators, class sizes, resources in school and classrooms, classroom instructional practices and the use of computers for instruction.

CHAPTER SEVEN

SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

As we have seen in the previous chapter, the majority of learners' homes are characterised by high levels of poverty, which is expressed as limited household assets and low levels of parental education. Lower levels of home educational capital restrict parents' ability to support their children in their academic pursuits, and most homes are unable to support learners substantively with subject matter. For those households that have high levels of income poverty and low educational capital, parents and society turn to schools as the institutions that would equalise opportunities for learners from poorer homes and level the playing field of educational success.

Well-performing schools generally serve learners from homes with at least basic assets and educational resources, and whose living conditions are above poverty levels. The school itself often has capable and competent leadership and management cultures. The school climate emphasises and promotes academic success, and staff are more likely to have safe and orderly working and learning environments.

In this chapter we will present the results for the following:

(i) The different school characteristics;
(ii) The school principals' demographics, as well as their leadership and management support characteristics; and
(iii) The school climate, both by describing the emphasis on academic success and promoting academic success; as well as the extent to which school discipline and safety problems, measured through the culture of safe and orderly schools and incidences of bullying, influence achievement.

7.1. SCHOOL CHARACTERISTICS

The schools that learners attend are part of the broader context within which they live and learn, and school characteristics shape the learning environment. The South African schooling system is made up of 95 percent of learners in public schools and 5 percent in independent[32] schools (DBE, 2020d). Public schools are state controlled, while independent schools are privately governed[33].

The legacy of apartheid policies is still felt in schools today. South African schools vary considerably with regard to the home background of learners, and access to infrastructure and resources. We describe the school characteristics in terms of classifications by the socioeconomic status (SES) of schools, learners' SES in schools, learners' population group, and the geo-location of schools.

Profile of schools by their socioeconomic status

The post-1994 state prioritised equitable funding to public schools to reduce disparities. Section 34(1) of the South African Schools Act 84 of 1996 states that in order to redress past inequalities in education provision, and to ensure the proper exercise of the rights of learners to education, the state must fund public schools from public revenue on an equitable basis (RSA, 1996c, p. 24). To this end, a school poverty index was created for each school (RSA, 2005). The National Norms and Standards for School Funding, Republic of South Africa, 2012a, p. 3) aimed to improve equity in funding for education by ranking each school into one of five quintiles. This ranking is based on the income, unemployment rate and literacy rates of the community in which the school is located. A Quintile 1 ranking indicates an impoverished school, and a Quintile 5 ranking indicates a wealthy or affluent school (van Dyk & White, 2019). This policy brings financial relief to parents of school-going children who would not be able to afford to pay school fees (in Quintile 1, 2 and 3 schools)[34], thereby being denied access to schools. Presently three-quarters of South African public schools are categorised as no-fee schools.

32 Independent schools are a diverse group ranging from schools receiving state subsidy to highly exclusive and high-fee schools.

33 Public schools are further divided into Section 20 and 21 schools, which relates to the function of School Governing Bodies (SGBs) as per the South African Schools Act (SASA) 84 of 1996 (RSA, 1996c). The SGBs of Section 21 schools are delegated greater governance and financial management powers by the provincial departments of education than the SGBs of Section 20 schools.

34 Initially funding was for Quintile 1 and 2 schools and was extended to include Quintile 3 schools in 2009.

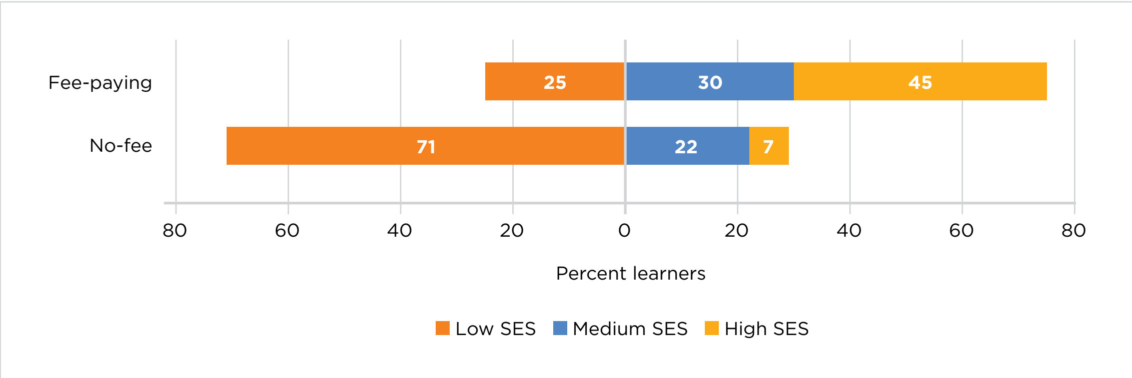
Profile of schools by socioeconomic status of learners

Since the Coleman report (Coleman et al, 1966), there has been great emphasis on how the socioeconomic composition of learners in the school is associated with individual learner achievement. Gruijters and Behrman (2020) highlight three ways through which family SES is likely to influence learning in francophone African countries: (1) home educational resources, (2) health and wellbeing, and (3) disparities in school quality. They found that school quality was regarded as particularly important and that improving the quality of all schools is a crucial mechanism for improving achievement.

The SES profile of learners in Quintile 1 to 5 public schools, and in independent schools, is shown in Figure 34 in Chapter Five. Figure 40 shows the socioeconomic profile of learners in no-fee and fee-paying schools. Overall, 71 percent of learners in no-fee schools had very few basic assets at home and were categorised as low SES. In the case of fee-paying schools, only a quarter (25%) of all learners were categorised as low SES. The stark differences in the SES of learners indicate that learners enter the education system with different levels of school readiness, support and resources, and learners in no-fee schools depend on school inputs to raise their education levels.

Figure 40 is a clear illustration of the continuity of conditions for learners from low SES homes to low SES schools. Learners from the poorest households attend the schools with the least resources and conditions that do not optimally support teaching and learning.

Figure 40: Profile of South African schools by SES of learners



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Profile of schools by population group of learners

During the apartheid period in South Africa, the Population and Registration Act (Republic of South Africa, 1950) categorised all South Africans by racial categories[35] (African, Coloured, Indian, White), making skin colour the single most important determinant in the lives of an individual. The home and school lives of learners from the different population groups were disparate, with the White group enjoying the most advantages and the African group being the most disadvantaged. The legacy of apartheid continues in the lives and lived experiences of South Africans. The post-apartheid education system sought to transform the education experiences of learners by deracialising schools.

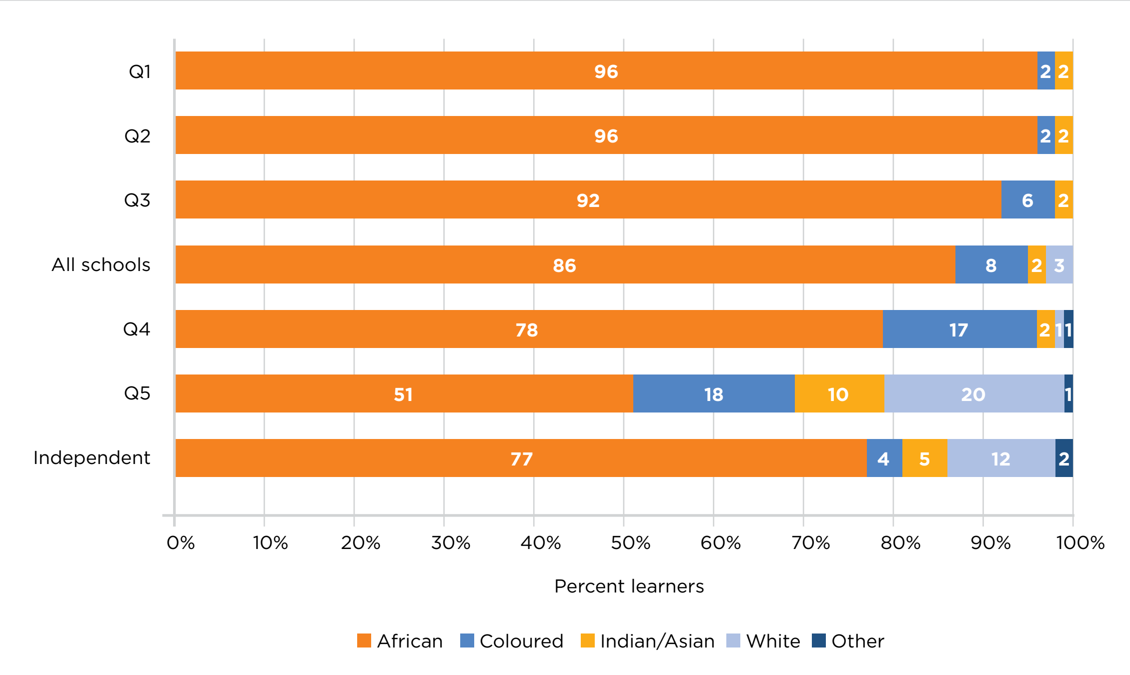
In 2019, the South African population was made up of 86 percent Black Africans, nine percent Coloured, 1.4 percent Indian or Asian and 4.4 percent White (StatsSA, 2019a). In the TIMSS questionnaire, learners were asked about the population group to which they belonged. Figure 41 reports the profile of schools by learners' population groups.

35 This report will use the term 'population groups'.

Learners in no-fee (Quintile 1, 2 and 3) schools were almost exclusively African, at 95 percent. African learners make up three quarters of the Quintile 4 (78%) and independent school (77%) cohorts and half (51%) of the Quintile 5 cohort. When exploring the learners' population group by quintile of school attended, almost all Indian (99%), White (99%) and 70 percent of Coloured learners, attended either Quintile 4, Quintile 5 or independent schools.

According to the Education Management Information Systems 2019 data, the learner population group profile in fee-paying schools was 60 percent African, 20 percent Coloured, 14 percent White and five percent Indian.

Figure 41: Percentage of learners by population group in different school types



Source: Author's own calculation from TIMSS 2019 South African Grade 9 dataset.

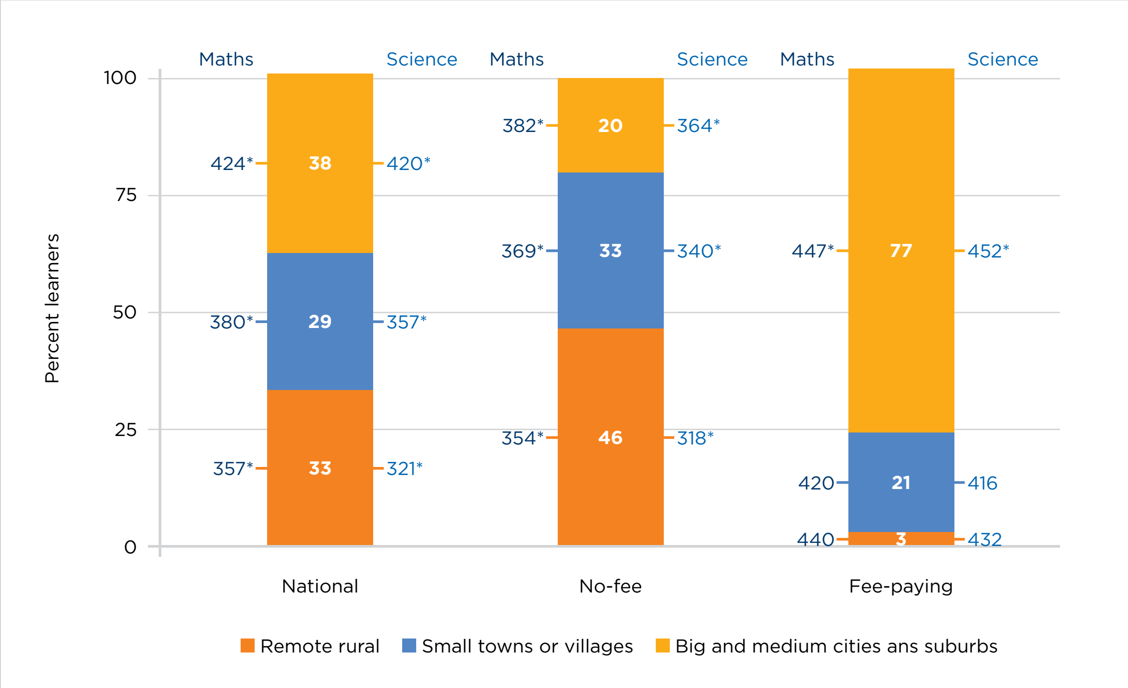
Profile of school by its geo-location

South Africa is a large and spatially diverse country. Learners and schools in remote areas are generally poorer, while schools in big cities and suburbs are more affluent and have better resources. Children in rural areas are largely from poor socioeconomic backgrounds. There are almost twice as many children living in rural areas (88%), facing multidimensional poverty, referring to the experience of multiple deprivations simultaneously, compared to their urban counterparts (41%) (StatsSA, 2020b).

Nationally, around a third of learners attended schools in each of the following three locations: big and medium cities and suburbs, small towns or villages, and remote rural areas. This profile is different for no-fee and fee-paying schools: three-quarters of learners attended fee-paying schools located in big and medium cities and suburbs, compared to 20 percent of no-fee learners. Just under half of the learners attended no-fee schools in remote rural areas.

We explored the relationship between where the school is located, and the mathematics and science achievement of learners attending the school (Figure 42). Learners attending schools in big and medium size cities and suburbs attained significantly higher mathematics and science achievement than those attending schools in small towns or villages (424 versus 380 for mathematics, and 420 versus 357 for science) or remote rural areas (424 versus 357 for mathematics, and 420 versus 321 for science). This relationship was robust at the national level as well as in no-fee schools. In fee-paying schools, learners attending schools in big and medium size cities and suburbs attained significantly higher mathematics and science achievement than those attending schools in small towns or villages.

Figure 42: Learners by school location and achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Note: The fee-paying rural school is probably an elite boarding school.

7.2. THE SCHOOL PRINCIPAL

The school 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 principals' qualifications and experience, as well as leadership and management styles, and educational achievement (Osborne-Lampkin, Folsom & Herrington, 2015). In this section we will report on the demographics of the principals at the TIMSS 2019 participating schools and describe the rating of the school principal on leadership and school management support characteristics.

School principals' educational qualifications and experience

Eighty percent of Grade 9 learners attended schools where the principal's qualification was a Bachelor's degree, 13 percent attended schools with a principal that had a postgraduate degree, and seven percent attended schools where the principal did not have any degree qualification (Table 16). The patterns are fairly similar in both public no-fee and fee-paying schools.

On average, learners attended schools where the principal had 9.2 years of experience. The average experience of principals was 9.8 years in fee-paying schools and 9.0 years in no-fee schools.

Table 16: Percentage of learners by principals' education level and school type

Principals' education level	School type		
	National	No-fee	Fee-paying
Completed post-graduate degree	13	12	15
Completed Bachelor's degree	80	81	79
Did not complete Bachelor's degree	7	7	7

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Principals' leadership and school management characteristics

The nature of school leadership and management has been recognised as an important enabler of quality teaching and learning, particularly for schools experiencing resource shortages. Zuze and Juan (2020), for example, showed that instructional leadership, and the promotion of a safe and orderly environment, promoted academic achievement in South African schools. In TIMSS 2019, educators rated the principal's leadership on seven statements and school management support on five statements. In Table 17 and Table 18 we report on mathematics educators' responses, by the percentage of learners who attended schools where principals' leadership and management support were rated highly.

Table 17: Percentage of learners attending schools where principals' leadership was highly rated

The principal...	Percent learners in schools rated 'Agree a lot'		
	National	No-fee	Fee-paying
lets the teaching staff know what is expected of them	76	77	73
is friendly and approachable	75	74	77
is willing to make changes	64	66	60
maintains definite standards of performance	64	63	63
puts suggestions made by the teaching staff into operation	59	61	54
treats all staff as his or her equal	59	62	51
explores all sides of topics and recognises that other opinions exist	55	54	54

Source: Author's calculations from TIMSS 2019 South African Grade 9 dataset.

Table 18: Percentage of learners attending schools where support by school management was rated highly

Support by school management...	Percent learners in schools rated 'high or very high'		
	National	No-fee	Fee-paying
to protect teaching and learning time	77	78	76
for educators' professional development	67	68	65
for instructional support to educators	66	65	67
to collaborate with educators to plan instruction	65	66	66
by observing teaching practices through classroom visits	53	53	55

Source: Author's calculations from TIMSS 2019 South African Grade 9 dataset.

Overall, the majority of learners were in schools where educators rated both the principal on their leadership attributes, and the school management for their support, positively. The same responses were observed in no-fee and fee-paying schools. Three-quarters of learners were in schools where educators reported that the principal let the teaching staff know what was expected of them and was friendly and approachable, and where the school management team protected teaching and learning time.

However, we must treat the high positive response with caution as there may be bias with participants providing socially desirable responses.

7.3. SCHOOL CLIMATE

School climate is a multidimensional index of factors that together provides a representation of the overall school atmosphere (Winnaar, Arends & Beku, 2018). Two characteristics of well performing schools are a positive school climate that emphasises and promotes academic success, and providing safe and orderly spaces for both learners and educators. In this section we report on schools' emphasis placed on academic success; the promotion of academic excellence in mathematics and science; and the extent of discipline and safety problems in schools, measured through levels of safety and orderliness, and bullying.

Emphasis placed on academic success

A positive school atmosphere with high expectations for academic excellence can contribute to the success of a school. Principals, and mathematics and science educators, rated their schools on 11 aspects relating to how educators, parents and learners emphasised academic success. Table 19 provides principals' responses, rating a given aspect as high or very high'. The results are reported as the percentage of learners attending schools given this rating for each statement.

Principals rated the educator, parent and learner aspects of emphasising academic success differently. Principals rated educators' emphasis on academic success highly, reporting that more than two-thirds of learners were taught by educators who understood curricula goals and were successful in implementing the curriculum, had high expectations for learner achievement, and inspired learners. Principals felt that parents had high expectations of learner achievement (51%), but that their involvement (18%), commitment (15%) and support (15%) related to school activities were low. According to the principals' ratings, 34 percent of learners respected academic excellence, and around a quarter had the ability (28%) and the desire (24%) to do well in school. This seems an unfair characterisation considering that 41 percent of learners scored above the low benchmark level.

These aspects were more positive in fee-paying than in no-fee schools.

Table 19: Principals' responses to the aspects of school emphasis on academic success (by percentage of learners)

Characteristics of school emphasis on academic success	Percent learners in schools rated 'very high or high'		
	National	No-fee	Fee-paying
EDUCATORS'…			
understanding of curricula goals	78	73	88
expectations for learner achievement	77	76	81
degree of success in implementing the schools' curriculum	66	58	82
ability to inspire learners	66	63	71
PARENTAL…			
expectations for learner achievement	51	45	64
involvement in school activities	18	14	27
commitment to ensure that learners are ready to learn	15	10	26
support for learner achievement	15	9	27
LEARNERS'…			
respect for classmates who excel academically	34	26	49
ability to reach school's academic goals	28	23	37
desire to do well in school	24	19	35

Source: Author's calculations from TIMSS 2019 South African Grade 9 dataset.

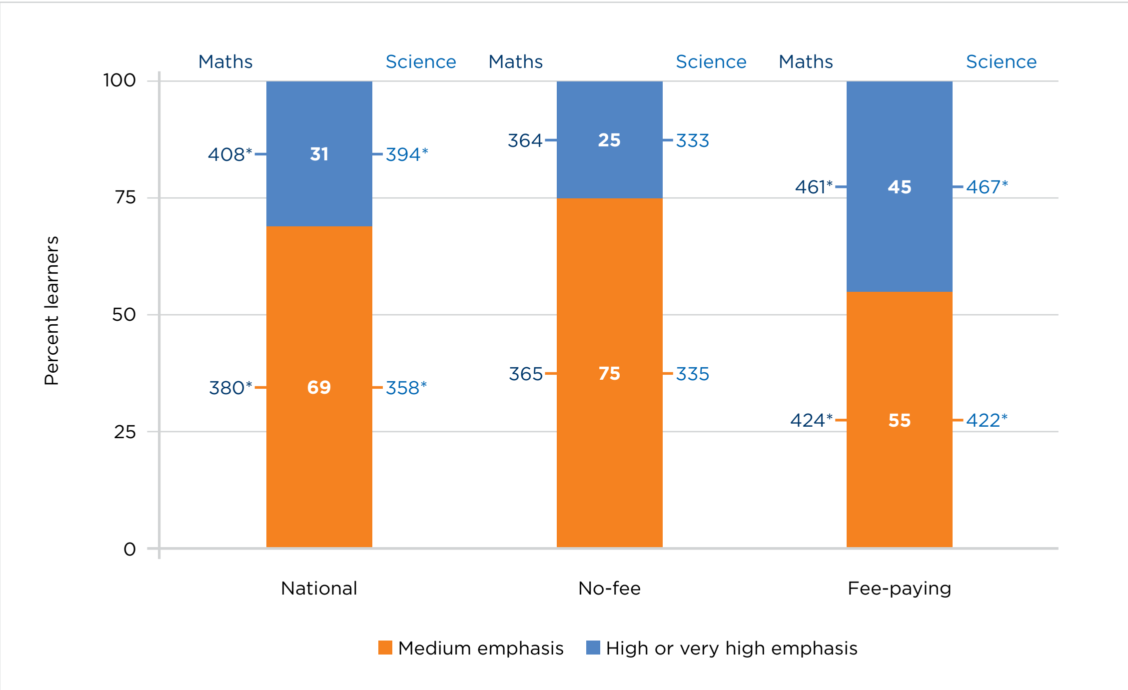
Based on the above set of items, TIMSS created a *School Emphasis on Academic Success Scale*[36]. Figure 43 reports the percentage of learners attending each of the school types by the emphasis placed on academic success, and the relationship with mathematics and science achievement. The categories used were the percentage of learners attending schools placing 1) *a medium emphasis* on academic success, or 2) *a high or very high emphasis* on academic success.

36 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *School Emphasis on Academic Success Scale* (Page 343).

In South Africa, 31 percent of learners attended schools that placed a 'high or very high' emphasis on academic success. This figure is lower than the international average of 57 percent. Learners in schools that placed a high or very high emphasis on academic success achieved significantly higher mathematics and science scores than learners who attended schools that placed a medium emphasis on academic success (408 versus 380 for mathematics, and 394 versus 358 for science).

A quarter of learners (25%) attended no-fee schools that placed a 'high or very high' emphasis on academic success, compared to 45 percent in fee-paying schools. In fee-paying schools, we observe significantly different achievement between schools placing a 'high or very high' or medium emphasis on academic success. However, in no-fee schools we did not observe a relationship between the level of emphasis placed on academic success and mathematics and science achievement.

Figure 43: Emphasis on academic success and mathematics and science achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Schools promoting academic excellence in mathematics and science

Schools are able to promote academic excellence through various activities. Principals in the TIMSS 2019 assessment responded to a set of eight items about activities in their school that promoted academic excellence in mathematics and science (Table 20).

From the principal reports, learners were exposed to school activities like extra lessons (64%), career information (58%) and extra time where educators worked with interested learners (58%). Just less than half of learners (49%) attended schools where improving mathematics and science education was stated as a specific goal and a third of the learners (35%) were in schools that used learner clubs and competitions to promote learner interest in mathematics and science. More learners in fee-paying schools than in no-fee schools were reported to benefit from the activities, which promoted academic excellence.

Table 20: Principals' responses, by percentage of learners, to school activities promoting academic excellence

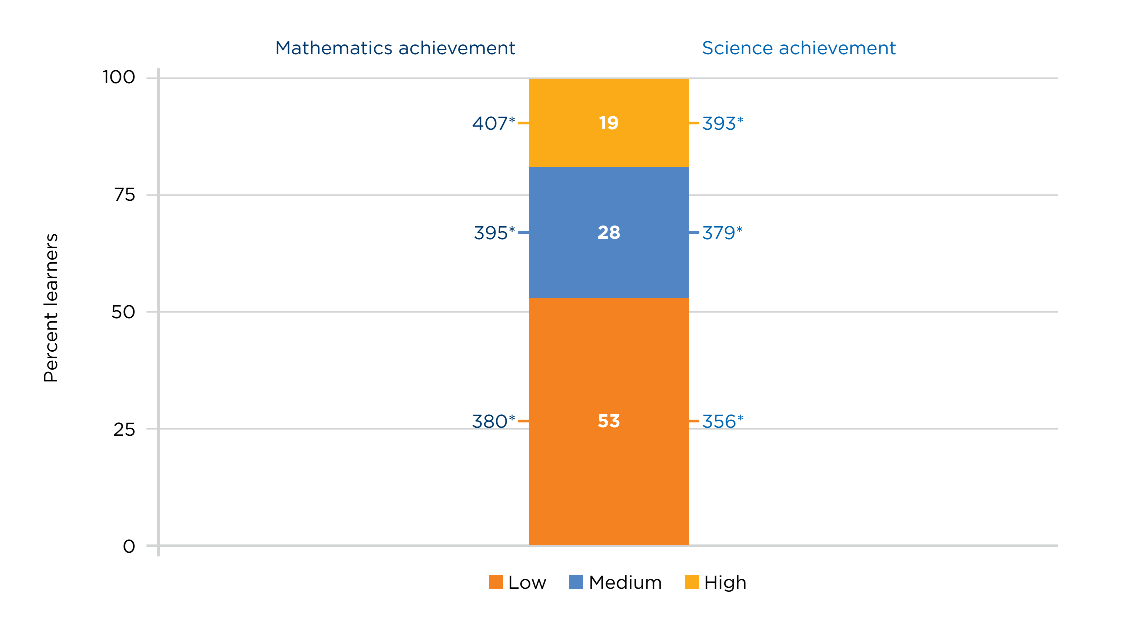
Activities to promote academic excellence	Percent learners in schools rated 'agree a lot'		
	National	No-fee	Fee-paying
The school provides extra lessons to help learners excel in mathematics and science	64	60	74
The school provides learners with information about career options in mathematics and science	58	54	66
The school encourages learners to continue studying mathematics and science in the future	58	55	62
Mathematics and science educators in this school spend extra time working with learners interested in mathematics and science	58	50	73
The school promotes professional development for educators of mathematics and science	52	49	60
The school has a specific goal to improve mathematics and science education	49	45	59
The school provides special activities in mathematics and science for interested learners	38	32	50
The school has initiatives to promote learner interest in mathematics and science (e.g. learner clubs, competitions)	35	34	35

Source: Author's calculations from TIMSS 2019 South African Grade 9 dataset.

Using six[37] of the eight items, the HSRC created a *School Promoting Academic Excellence Scale*. Figure 44 shows the relationship between the extent to which schools promoted excellence in mathematics and science (*low, medium or high*), and learners' achievement in these subjects. One in five learners (19%) were in schools where there were a high number of activities promoting academic excellence, while the majority of learners (53%) were in schools with a low number of activities promoting academic excellence. Learners who experienced more school activities that promoted academic excellence in mathematics and science achieved significantly higher scores in these subjects in the TIMSS assessment than learners who experienced a low number of activities (407 versus 380 for mathematics and 393 versus 356 for science).

37 (i) School promotes professional development for educators of mathematics and science; (ii) School provides extra lessons to help learners excel in math and science; (iii) School provides special activities in math and science for interested learners; (iv) School has specific goal to improve math and science education, and (v) Math and science educators spend extra time working with learners interested in mathematics and science.

Figure 44: Learners in schools promoting excellence and mathematics and science achievement



* Statistically significant achievement difference between categories.

Source: TIMSS 2019 South African Grade 9 dataset.

Safe and orderly schools

TIMSS reports have consistently shown a positive relationship between learner achievement, and educator and principal reports that the school is safe and orderly. School effectiveness research analysing TIMSS/PIRLS 2011 data showed that school safety was an important factor associated with learner achievement in many countries (Martin, Foy, Mullis & O'Dwyer, 2013). The sense of security that comes from having minimal behavioural problems, and little or no concern about learner or educator safety at school, promotes a stable learning environment (Winnaar et al., 2018).

TIMSS asked educators to report on the characteristics of their schools' safety and discipline. Table 21 reports on responses from mathematics educators[38] about the characteristics of safe and orderly schools.

About half of the learners were in schools that had clear rules about learner conduct, and where the rules were enforced in a fair and consistent manner. However, there were concerns about safety in schools, with only one-third of learners attending schools that were reported to be located in a safe neighbourhood, and one-quarter attending schools where the educators felt safe. Educators expressed concerns about the behaviour of learners, with only 16 percent of learners reported to behave in an orderly manner, 16 percent being respectful of educators, and 11 percent respecting school property.

Within the environment of low levels of safety and orderliness in schools, learners in no-fee schools were more often in unsafe conditions relative to their counterparts in fee-paying schools.

38 Responses from science educators were similar.

Table 21: Educator response, by percentage of learners, to the characteristics of safe and orderly schools

Characteristics	Percent learners in schools rated 'Agree a lot'		
	National	No-fee	Fee-paying
The school has clear rules about learner conduct	57	56	60
The school's rules are enforced in a fair and consistent manner	45	42	50
The school is located in a safe neighbourhood	32	25	46
I feel safe at this school	26	19	42
The school's security policies and practices are sufficient	23	16	37
The learners behave in an orderly manner	16	11	26
The learners are respectful of educators	16	11	26
The learners respect school property	11	7	19

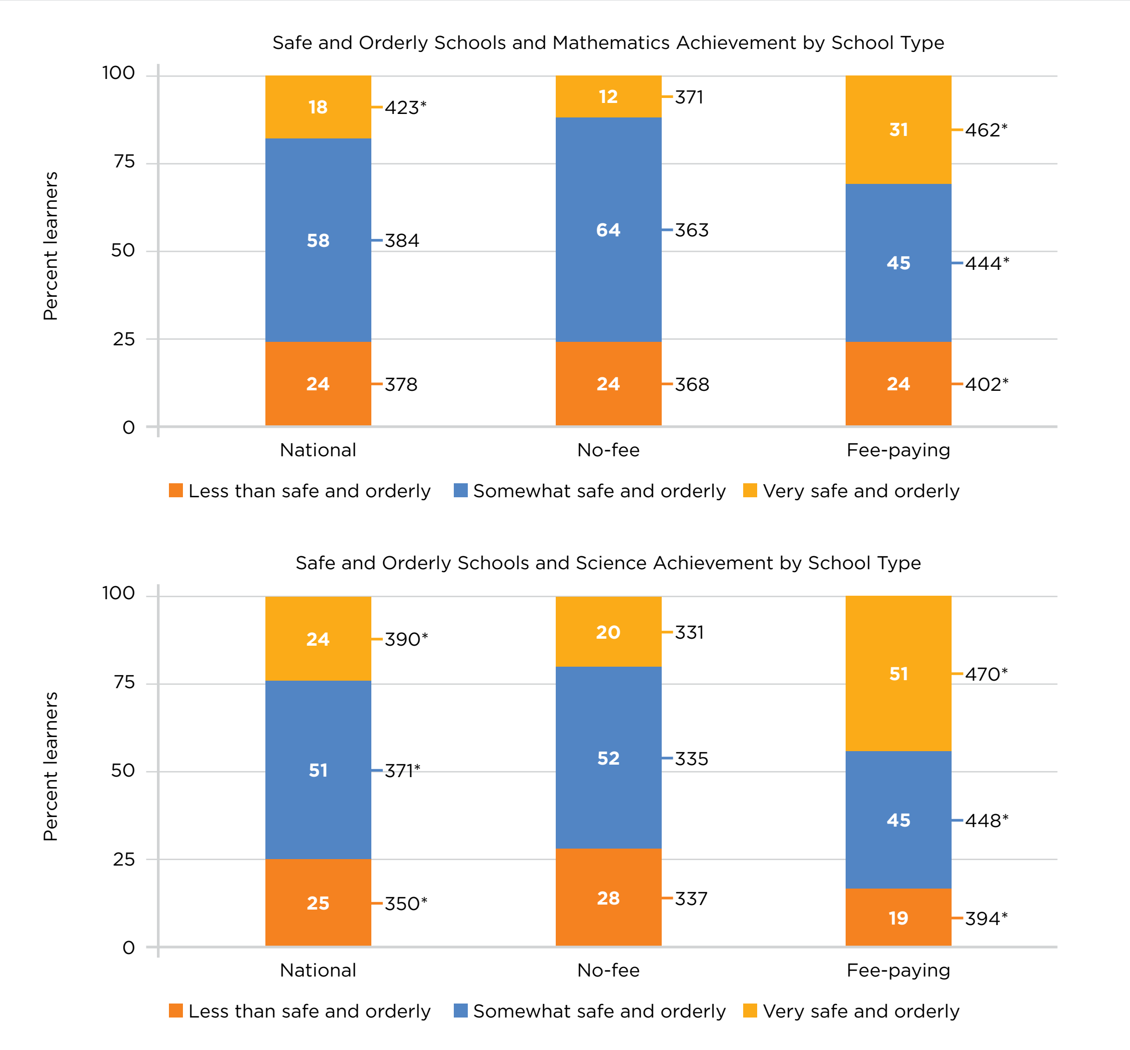
Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

TIMSS 2019 used the eight characteristics to create a *Safe and Orderly School Scale*[39]. The scale was divided into three categories, with learners attending schools that were: 1) *very safe and orderly*, 2) *somewhat safe and orderly*, or 3) *less than safe and orderly*.

Figure 45 reports on the relationship between the extent to which schools were safe and orderly, and achievement by school type. Learners in schools considered to be safer and more orderly significantly outperformed learners that were in schools that were less safe and orderly (423 versus 378 for mathematics, and 390 versus 350 for science).

39 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *Safe and Orderly School Scale* (Page 365).

Figure 45: Learners in safe and orderly schools and mathematics and science achievement



* Statistically significant achievement scores between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

School discipline

In order for schools to be effective, an orderly environment must be ensured through fair and positive discipline that promotes appropriate learner behaviour. A general lack of discipline, especially to the extent where learners and educators are afraid for their safety, does not facilitate learning and is related to lower academic achievement (Milam, Furr-Holden & Leaf, 2010). However, learner indiscipline has been repeatedly reported as a problem within South African schools (Pretorius, 2014). Learner indiscipline, such as ignoring educator instructions or leaving the classroom during lessons, negatively impacts achievement (Ogbonnaya, Mji & Mohapi, 2016).

Principals were asked to what extent the 11 behaviours in Table 22 were a problem among learners in their school. We report on the percentage of learners attending schools that experienced 'severe problems'.

Close to a quarter of the learners were in schools where incidences of theft, vandalism, learners arriving late at school, and absenteeism were rated a severe problem. There were higher levels of these discipline problems in no-fee schools than in fee-paying schools.

Table 22: Principal response, by percentage of learners, to learners' poor discipline in schools

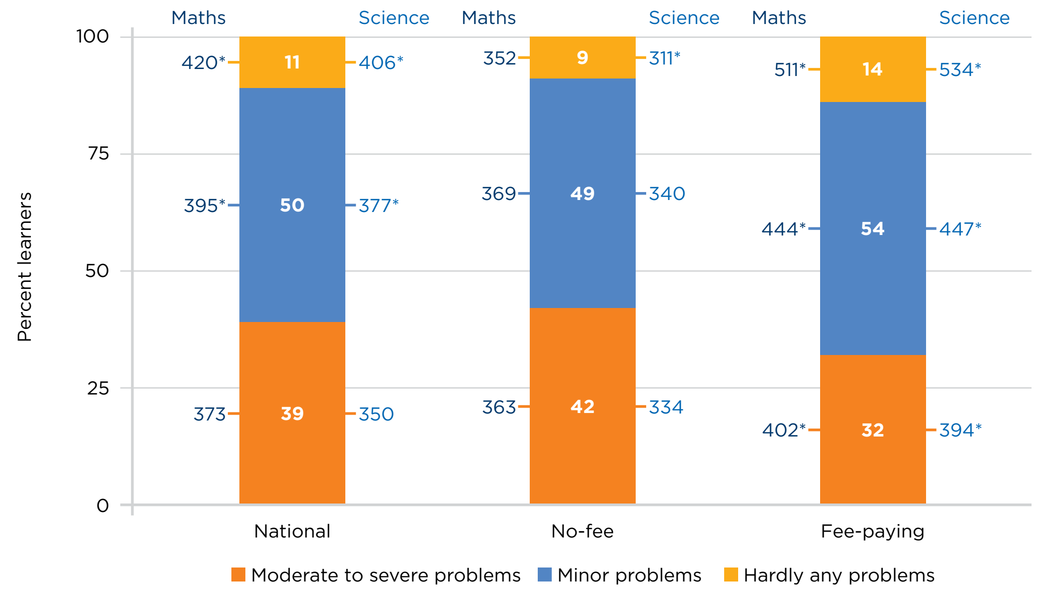
Behaviours in school	Percent learners in schools rated 'severe problem'		
	National	No-fee	Fee-paying
Physical injury to educators or staff	2	2	2
Intimidation or verbal abuse of educators or staff	6	7	5
Physical injury to other learners	7	7	7
Cheating	7	8	4
Profanity	9	9	10
Intimidation or verbal abuse among learners	16	15	17
Classroom disturbances	17	18	16
Theft	22	25	16
Vandalism	27	33	14
Arriving late at school	21	23	16
Absenteeism	22	24	16

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

TIMSS used these eleven behaviours to create a *School Discipline Scale*[40]. Three categories were included in the scale: 1) *moderate to severe* problems, 2) *minor* problems, and 3) *hardly any* problems. Figure 46 reports on the relationship between school discipline and achievement by school type. Thirty-nine percent of South African learners experienced 'moderate to severe problems' in comparison with the international average of 11 percent.

Nationally and in fee-paying schools, learners who experienced hardly any problems or minor problems significantly outperformed learners in schools with moderate or severe problems. In no-fee schools, there was no association between the extent of discipline problems experienced, and learners' mathematics and science achievement.

Figure 46: Learners' experience of school discipline and mathematics and science achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

40 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *School Discipline and Safety Scale* (Page 359).

Incidences of bullying in schools

Bullying involves repeated aggressive behaviour intended to harm another individual. Previous TIMSS results have shown that bullied learners tend to have lower mathematics and science achievement, aligning with other research findings (Konishi et al., 2010; Rutkowski & Engel, 2013). Bullying is related to school climate, with less incidents of bullying being associated with a positive school climate (Juan et al., 2018).

TIMSS 2019 Grade 9 learners reported on how often they experienced bullying behaviours (physical, verbal or through digital devices) at school. We report the percentage of learners who 'never or almost never' experienced bullying (Table 23).

On average, four in five learners did not experience any form of cyber bullying, three in four learners never or almost never experienced physical bullying, and two in three learners rarely or never experienced verbal bullying. The converse of this is that 20 percent of learners did experience some form of cyber bullying, 25 percent experienced physical bullying, half of the learners had something stolen from them, and one-third of learners experienced some form of verbal bullying. This represents high levels of bullying behaviours in schools, and this may be reflective of the extent of bullying and violence in the communities that surround the schools.

Table 23: Percentage of learners who were never or almost never bullied in schools

Behaviours	Percent learners 'never or almost never bullied'		
	National	No-fee	Fee-paying
Verbal			
Insulted a member of my family	74	71	81
Shared my secrets with others	71	69	76
Refused to talk to me	65	61	73
Spread lies about me	64	62	69
Said mean things about my physical appearance	54	50	63
Average for verbal bullying	**66**	**63**	**72**
Physical			
Made me do things I did not want to do	77	73	84
Threatened me	79	75	86
Physically hurt me	78	74	86
Damaged something of mine on purpose	73	69	80
Stole something from me	49	46	55
Average for physical bullying	**71**	**67**	**78**
Cyber			
Shared embarrassing photos of me online	88	85	94
Sent me nasty or hurtful messages online	79	75	87
Shared nasty or hurtful things about me online	82	79	89
Average for cyber bullying	**83**	**80**	**90**

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

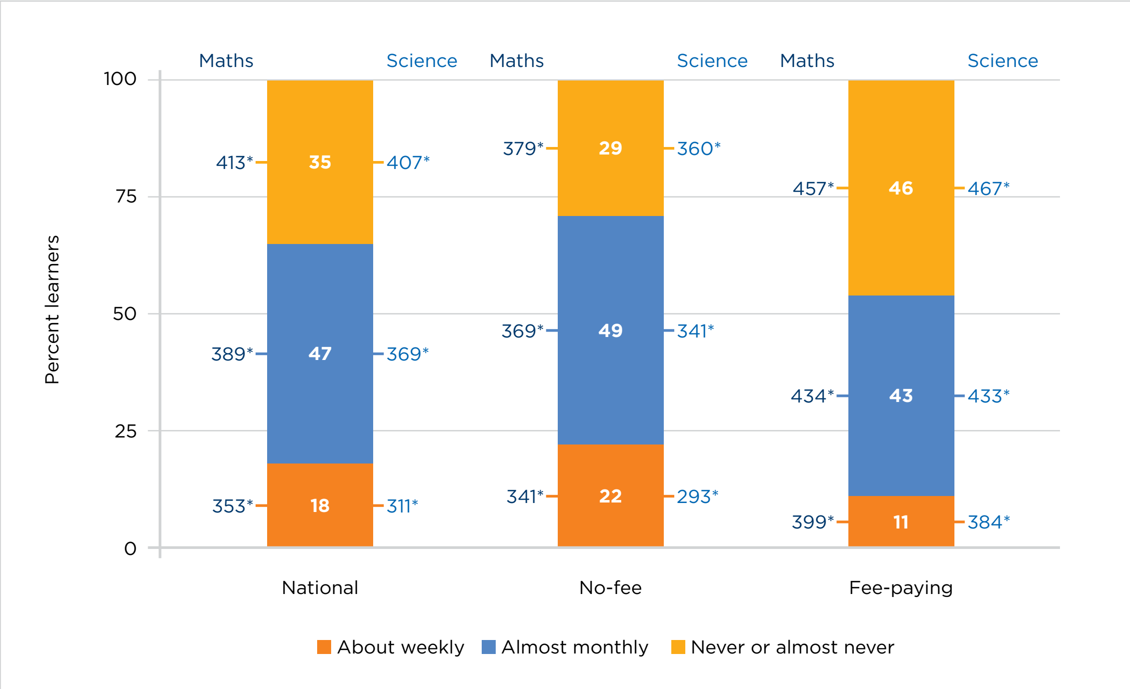
TIMSS 2019 used the 13 behaviours to create a *Learner Bullying Scale*[41]. The scale used three categories: 1) bullied *about weekly*, 2) bullied *almost monthly*, and 3) *never or almost never* bullied. Figure 47 reports on the relationship between bullying and achievement by school type.

41 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *Learner Bullying Scale* (Page 374).

South Africa experienced higher levels of bullying than most participating countries. Only a third (35%) of South African Grade 9 learners reported 'never or almost never' being bullied, compared to the international average of 71 percent.

Learners who hardly experienced any form of bullying achieved significantly higher mathematics and science scores than learners who experienced bullying about weekly (413 versus 353 for mathematics, and 407 versus 311 for science). The same pattern is observed in no-fee and fee-paying schools.

Figure 47: Learner experiences of bullying and mathematics and science achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

This chapter has focused on school factors that promote an enabling environment for teaching and learning. The following infographic presents a summary of these factors.

7.4. SUMMARY: SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

Home to school continuities

The majority of South African learners' homes are characterised by high levels of poverty. For those households that have high levels of income poverty and low educational capital, parents and society turn to schools as the institutions that would equalise opportunities for learners from poorer homes and level the playing field of educational success.

However, there is a continuity of SES from homes to schools – learners who come from low-income households with fewer assets attend schools with limited access to resources and poorer teaching and learning cultures. Advantage begets advantage, and learners from more affluent households enter schools that are better functioning.

School characteristics

Nationally, 20 percent of South African households were categorised as having high SES, 25 percent as medium SES and 55 percent as low SES. The high level of home inequality means that learners enter schools with different levels of school readiness, support and resources.

Learners attending no-fee schools (Quintile 1, 2 and 3) were almost exclusively Black African. Black African learners make up three-quarters of the Quintile 4 and independent school cohorts and half of the Quintile 5 cohort. Almost all Indian and White, and 70 percent of Coloured learners attended fee-paying schools.

Thirty-eight percent of learners attended schools in big and medium cities and suburbs, 29 percent in small towns or villages, and 33 percent in remote rural areas. Learners attending schools in big and medium size cities and suburbs attained significantly higher mathematics and science achievement than those attending schools in villages or remote rural areas.

School climate: Emphasising academic success

A key characteristic of a well-performing school is a positive school climate that emphasises and promotes academic success. Principals rated the mathematics and science educators highly on aspects emphasising academic success but were less positive about parental and learner behaviours that emphasised academic success.

Just under one-third (31%) of learners attended schools that placed a high emphasis on academic success, and these learners achieved significantly higher mathematics and science scores than learners who attended schools that placed a medium emphasis on academic success.

School climate: Safe and orderly schools, school discipline, and learner bullying

Another characteristic of a well-performing school is that it provides safe and orderly spaces for both learners and educators. Eighteen percent of learners attended schools that educators rated as very safe and orderly. School discipline problems were widespread, with only 11 percent of learners attending schools that principals characterised as having hardly any problems. Learner bullying was also widespread, and two in three learners reported that they experienced incidences of bullying in school.

All three school climate factors (safe and orderly schools, school discipline, and learner bullying) were significantly associated with mathematics and science achievement. Learners who were in more safe and orderly schools, with hardly any discipline problems, and who hardly experienced any form of bullying achieved significantly higher mathematics and science scores.

In the next chapter, we turn to the classroom factors, including educator characteristics, that promote effective teaching and learning.

CHAPTER EIGHT

CLASSROOMS: EDUCATORS, RESOURCES AND INSTRUCTIONAL PRACTICES

The majority of teaching and learning takes place in the classroom. Successful learning is likely to be affected by the calibre of educators, the quality of classroom environments and instructional activities, as well as the resources available to support instruction. South African learners enter schools and classrooms with different levels of readiness for learning. Educators have the dual responsibility to structure the learning process to start where the learner is and complete the learning outcomes designed for that grade.

In this chapter we will report on:

(i) Educator demographics, preparation, and experience;
(ii) Class size, and mathematics and science achievement;
(iii) Resources in schools and classrooms to teach mathematics and science;
(iv) Classroom instructional practices; and
(v) Use of computers for instruction.

8.1. EDUCATORS

Preparation and experience

There is a body of evidence showing that educator preparation is related to learner achievement. Prospective educators need adequate preparation to gain the relevant subject matter knowledge in the subjects that they will teach, to understand how learners learn, and to learn about effective pedagogy in teaching mathematics and science (Arends, Winnaar & Mosimege, 2017; Lay & Chandrasegaran, 2018). Ongoing professional development activities can help educators to increase their effectiveness, broaden their knowledge, and expose them to recent developments such as curricula changes and new technologies for classroom instruction.

Table 24 describes the percentage of learners taught by educators by the demographics of gender, age, teaching experience, educational qualifications, subject specialisation and educators' job satisfaction levels.

Table 24: Percentage of learners taught by educators with each characteristic

	Percent learners taught by mathematics educators	Percent learners taught by science educators
Gender		
Taught by female educators	45	55
Taught by male educators	55	45
Educator age		
Less than 29 years	23	22
30-39 years	24	24
40-49 years	30	27
Over 50 years	23	27
Average teaching experience	**14 years**	**15 years**
Educational qualification		
Finished Grade 12	-	2
Finished Diploma	20	16
Finished First degree	58	53
Finished Honours or higher	22	29
Subject specialisation	91% of learners taught by educators with specialisation in mathematics	86% of learners taught by educators with specialisation in science
Educator satisfaction levels	64% learners taught by educators who are very satisfied in their job	57% learners taught by educators who are very satisfied in their job

Source: TIMSS 2019 South African Grade 9 dataset.

Close to half of the learners were taught mathematics and science by a female educator. There was a reasonably normal age distribution of educators, so that as older educators leave the education system there is a pipeline of new educators moving up to take their place. The average teaching experience of South African mathematics educators was 14 years, and for science educators it was 15 years, compared to 16 years for the international average.

Educators with the requisite subject knowledge and experience contributed to higher mathematics and science achievement. Eighty percent of learners were taught by mathematics and science educators with at least a Bachelor's degree qualification, compared with 96 percent of learners internationally. There were no significant achievement differences for learners taught by mathematics educators with a diploma or a degree qualification. The picture is different for science, however, where learners taught by educators with a degree qualification significantly outscored learners taught by educators without a degree. Ninety-one percent of mathematics learners and 86 percent of science learners were taught by educators who reported a subject specialisation. There were no significant achievement differences for learners taught by educators with or without a subject specialisation. We were unable to confidently corroborate educator qualifications and specialisations with other data. The Sustainable Development Goals: South African Country Report 2019 stated that 91 percent of educators had the minimum required qualifications of either a three-year teacher's diploma or a three-year degree (StatsSA, 2019b).

The profiles of mathematics and science educators in both no-fee and fee-paying schools were similar.

Educator professional development participation and future needs

Mathematics and science educators were asked about the professional development activities in which they had *participated*, in the preceding two years, in the following areas: content, curriculum, assessment, pedagogy, integrating technology into lessons, improving learners' critical thinking, and addressing individual learner needs. In addition, educators were asked about their need for future professional development in the same areas.

Figure 48 reports on the percentage of learners taught by mathematics and science educators in relation to their professional development participation and needs. The professional development programmes, largely, would have been coordinated by the provincial and district level education authorities.

Figure 48: Percentage of learners by mathematics and science educators' participation (in the preceding two years), and need for professional development activities

Professional development activities	Mathematics educators		Science educators	
	Mathematics educators participation in professional development	Mathematics educators need for professional development	Science educators participation in professional development	Science educators need for professional development
Content	84	77	67	72
Curriculum	74	71	68	69
Assessment	70	77	57	76
Pedagogy/Instruction	58	81	44	76
Improving learner's critical thinking or problem-solving skills	56	89	43	85
Addressing individual learner needs	50	86	40	81
Integrating technology into instruction	46	88	38	81

Source: TIMSS 2019 South African Grade 9 dataset.

The majority of mathematics and science professional development activities related to curriculum, content and assessment – these are important interventions in the context of poor achievement. There were fewer activities relating to integrating technology into instruction and addressing individual learner needs. The latter topics would be largely relevant for more resourced environments. An unexpected finding was the low level of professional development activities related to pedagogy or instruction, a key factor in improving educational achievement.

In terms of future professional development needs, educators requested activities related to improving critical thinking, integrating technology into instruction, addressing individual learner needs, and pedagogy.

Educators were also asked when the professional development activities usually take place. About half of the educators reported that the activities took place during school hours, a quarter after school, and the other quarter on weekends or during school holidays. The implication of professional development activities conducted during school hours is that learners would lose teaching and learning time, leading to negative impacts on achievement.

8.2. RESOURCES TO TEACH MATHEMATICS AND SCIENCE

Class size and achievement

According to the Personnel Administrative Measures Government Gazette (DBE, 2016), the ideal maximum Grade 9 class size is 37 learners. During the logistical planning of the TIMSS 2019 assessment in South Africa, classes that were sampled to participate in the study submitted the names of all learners in that class. This was captured on the TIMSS WinW3S software. We included the total number of learners as a variable onto the TIMSS dataset, which included learner and school information, as well as the mathematics and science achievement plausible values.

In low-income countries, we start with the position that a classroom should not have more than 40 learners per class and contend that it is a violation if more than 50 learners are crammed into a classroom designed for 40 learners, sitting three to a two-learner desk, while the educator is asked to provide individual attention to a grossly overcrowded class. Table 25 reports the average TIMSS 2019 Grade 9 class sizes, by the quintiles of public schools, and for independent schools.

Table 25: Average class size (with standard deviation) for National, Quintiles 1-5, and independent schools in TIMSS sample

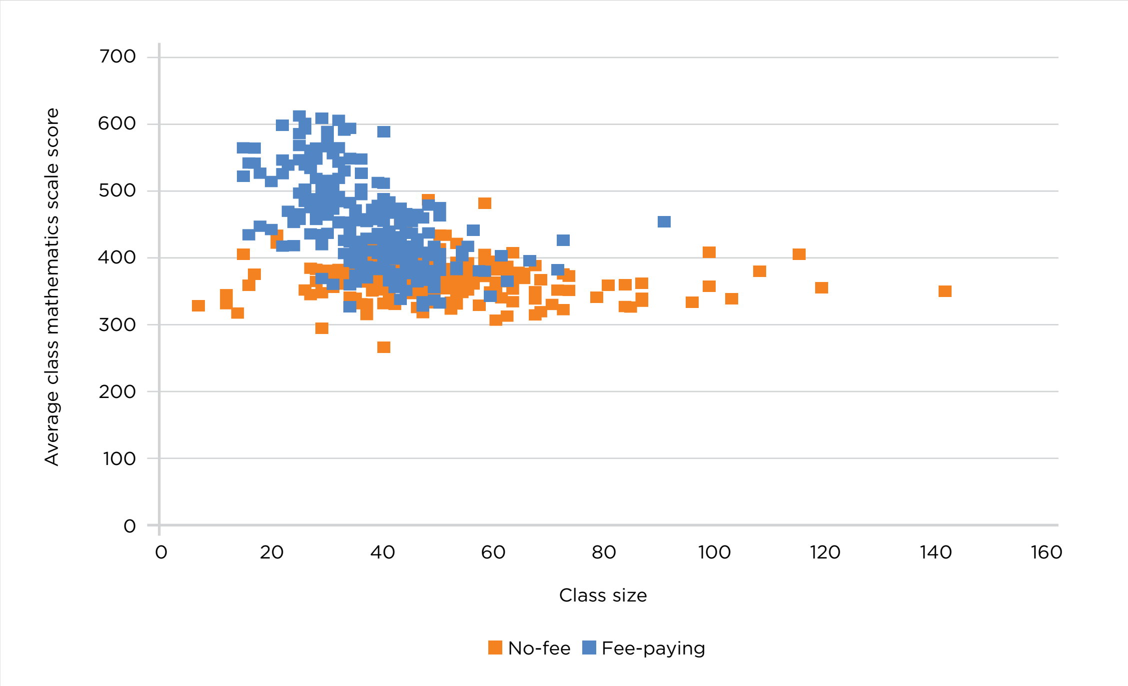
	National (SD)	Quintile					Independent (SD)
		1 (SD)	2 (SD)	3 (SD)	4 (SD)	5 (SD)	
Class size: number of learners	51 (18.9)	53 (17.1)	58 (22.4)	56 (18.9)	48 (13.0)	37 (6.8)	29 (8.7)

Source: Author's own calculation from TIMSS 2019 South African Grade 9 dataset.

The average TIMSS 2019 Grade 9 class size was 51 learners. Quintile 1, 2 and 3 schools (i.e. no-fee schools) had similar average class sizes, clustered around 56 learners per class. Quintile 4 schools had slightly smaller class sizes, with an average of 48 learners per class. Quintile 5 schools with an average of 37 learners and independent schools with an average of 29 learners, had the smallest class sizes.

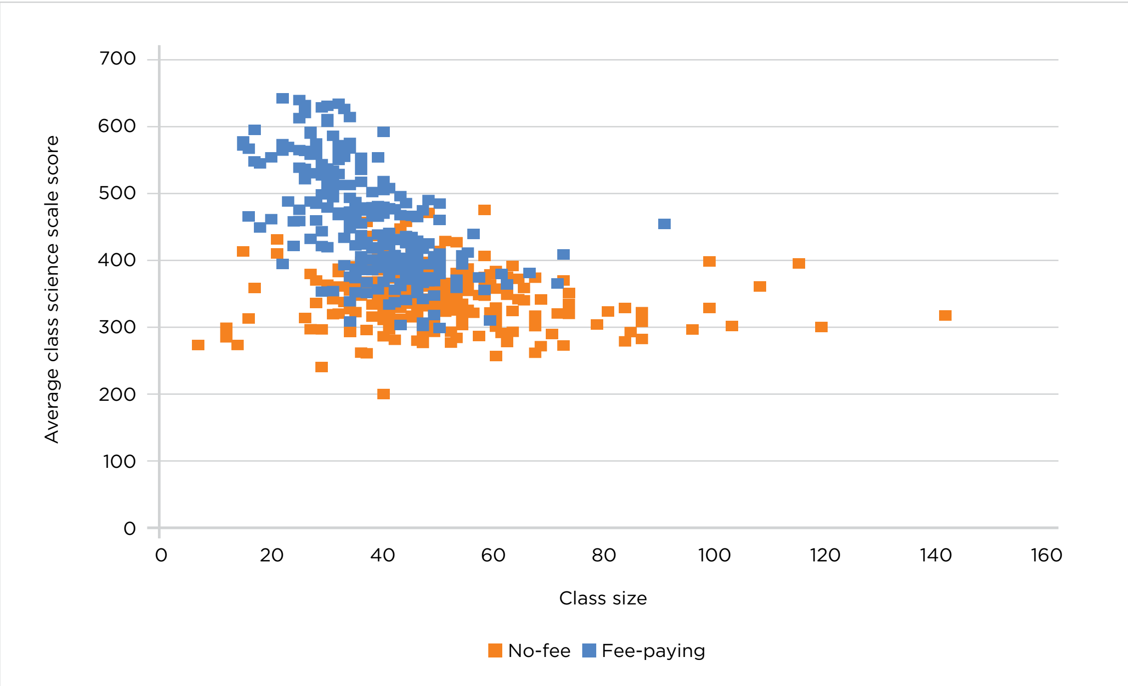
The TIMSS class sizes ranged from seven to 140 learners. Three in ten learners attended classes with fewer than 40 learners; while the majority, seven in ten learners, attended classes with more than 40 learners. These conditions are not optimal to promote teaching and learning. In order to explore the relationship between class size and achievement, we calculated the average mathematics and science achievement for each TIMSS class. Figure 49 and Figure 50 portray the scatterplots of TIMSS 2019 class size and achievement for no-fee and fee-paying schools.

Figure 49: Average class mathematics scale score, by class size and school status



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Figure 50: Average class science scale score, by class size and school status

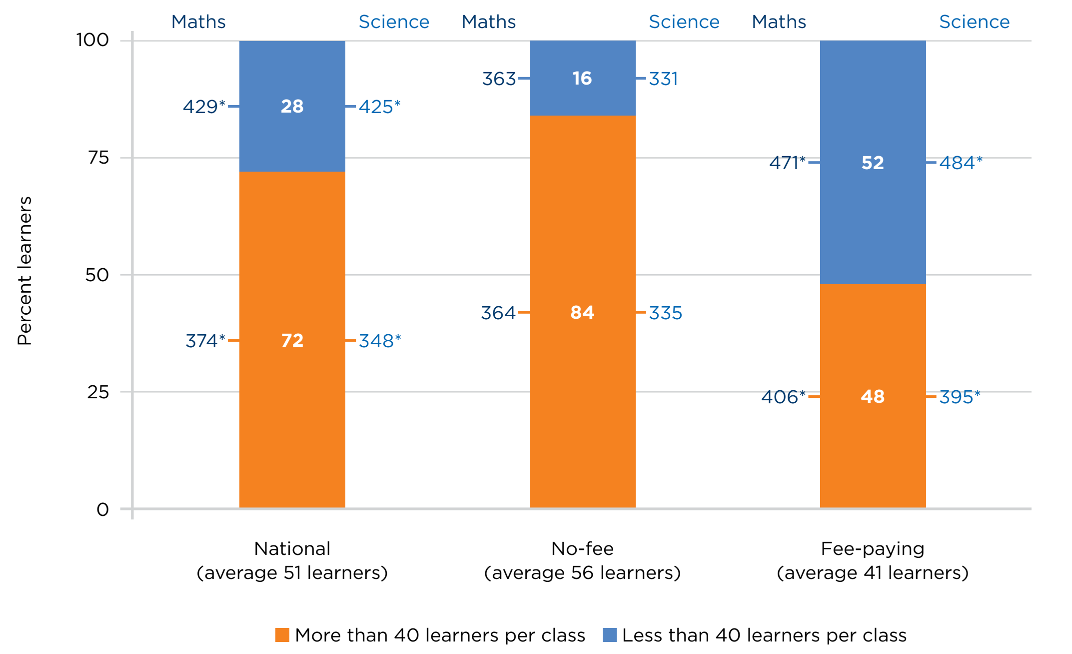


Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

We explored the association between class size, and mathematics and science achievement further for South Africa, and for no-fee and fee-paying schools. The average class size in no-fee schools was 56 learners, and only 16 percent of learners were in classes with less than 40 learners. In fee-paying schools, the average class size was 41 learners, and half of the learners (52%) were in classes with fewer than 40 learners.

Learners in classes with fewer than 40 learners scored higher average mathematics and science achievement than those in classes with more than 40 learners (429 versus 374 for mathematics, and 425 versus 348 for science) (Figure 51). We observed the same pattern for learners in fee-paying schools, but there was not any significant achievement difference in no-fee schools. This could be due to the multitude of factors that affect learning in no-fee schools and the fact that 84 percent of learners were in classes with over 40 learners.

Figure 51: Percentage of learners by class size and mathematics and science achievement



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Resources and materials

The resources available in a school and its classrooms are expected to influence the quality of instruction, learning, and subsequently, achievement. Table 25 reports on principals' rating of how instruction in the school was affected by the availability of mathematics and science resources.

According to the principal reports, just over half of the learners attended schools that were affected by shortages of educators with specialisations in mathematics and science. This was different from educators who reported that 96 percent of mathematics educators and 86 percent of science educators had specialist qualifications (Table 26). Half of the learners attended schools that experienced substantial shortages of instructional materials for mathematics and science, as well as concrete objects and science equipment to understand the subject content.

Table 26: Percentage of learners affected substantially[42] by a shortage in the following factors

Resources for Mathematics	Percent learners affected substantially	Resources for Science	Percent learners affected substantially
Educators with specialisation in mathematics	56	Educators with specialisation in science	52
Calculators for mathematics instruction	54	Calculators for science instruction	48
Adequate instructional materials and supplies are a problem in mathematics[43]	54	Adequate instructional materials and supplies are a problem in science	56
Concrete objects or materials to help learners understand quantities or procedures	47	Science equipment and materials for experiments	49
Library resources relevant to mathematics instruction	43	Library resources relevant to science instruction	40

Source: TIMSS 2019 South African Grade 9 dataset.

Textbooks and workbooks

Key teaching and learning resources in the classroom are textbooks and workbooks. The state has invested in the provision of mathematics and science textbooks and workbooks to learners. Figure 52 reports on the availability of Grade 9 mathematics textbooks and workbooks, and Figure 53 reports access to these resources for science.

Learners had better access to mathematics text resources, with 88 percent either owning or sharing a mathematics textbook, and 92 percent either owning or sharing a mathematics workbook. This aligns with the figures in the School Monitoring Survey 2017/2018 (DBE, n.d.) which reported that 83 percent of Grade 9 learners had access to a mathematics textbook. A small number of learners (3.5 percent) have neither a mathematics workbook nor a textbook.

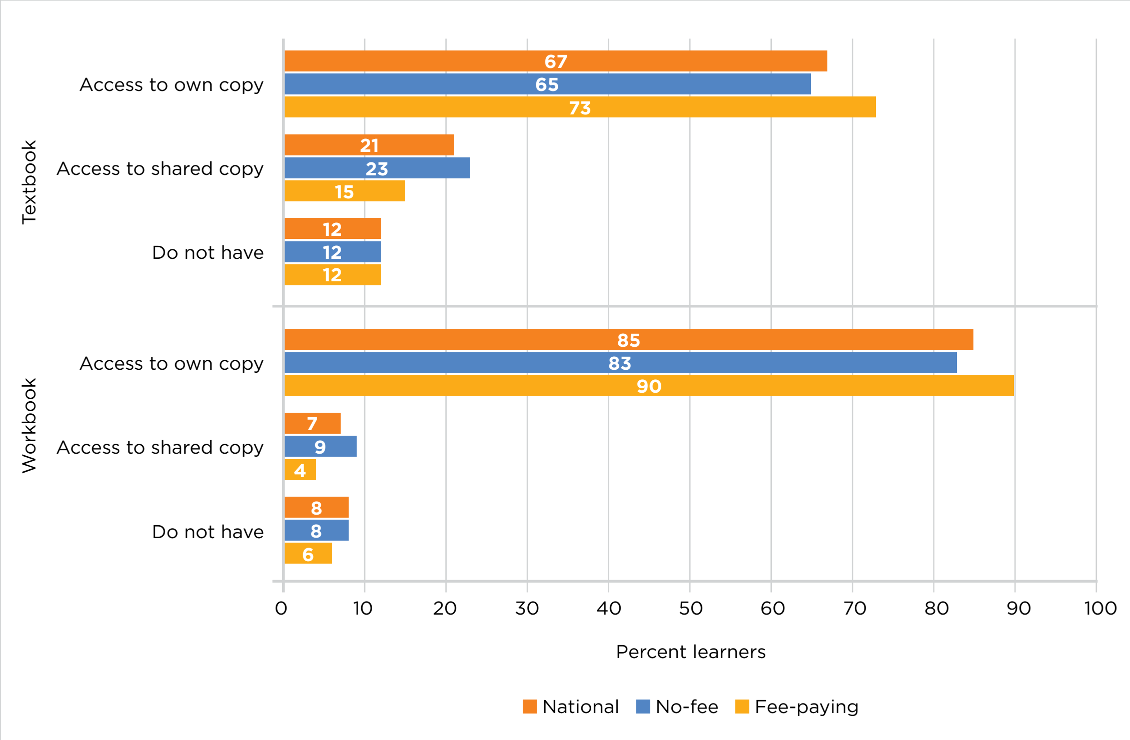
For science the picture was different, with 20 percent of learners reporting that they did not have a science textbook, and one-third not having science workbooks[44]. Unfortunately, 17 percent of learners had neither a science workbook nor a textbook. Learners in fee-paying schools had greater access to mathematics and science textbooks and workbooks than learners in no-fee schools.

42 Response by principal was ‘Some’ or ‘A lot’ which were combined to form ‘substantial’.

43 This item is from the Educator Questionnaire and responses ‘Moderate’ and ‘Serious’ were combined to form ‘substantial’.

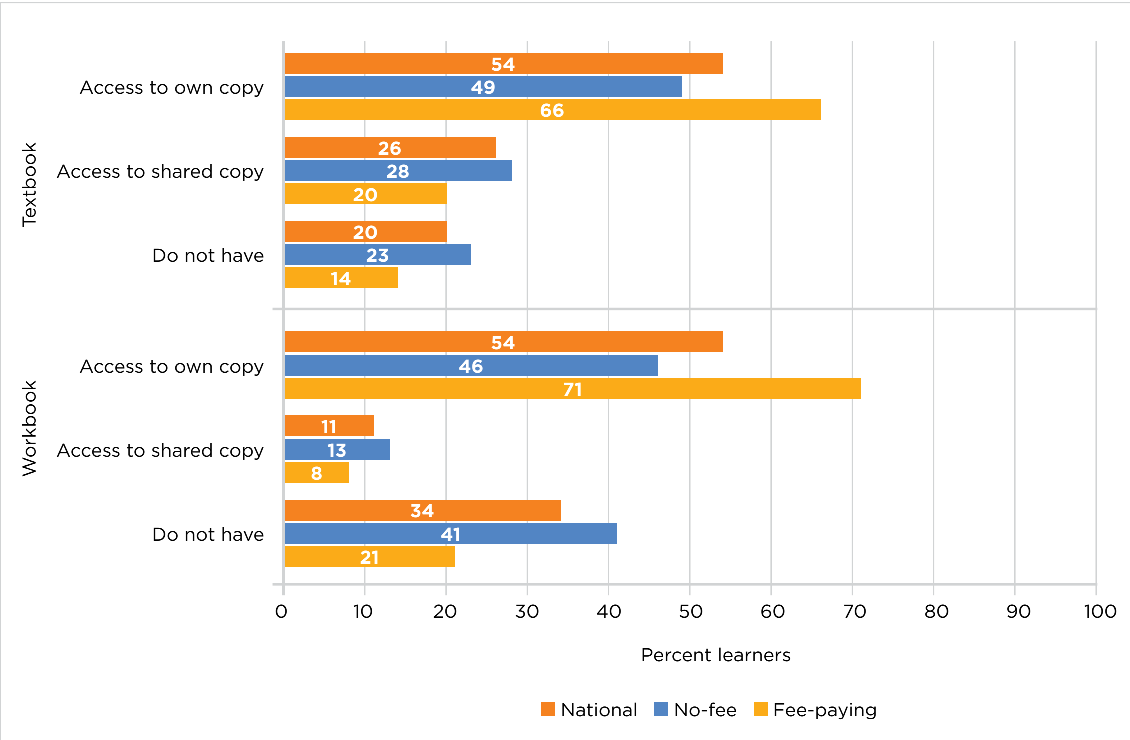
44 The DBE provides mathematics and language workbooks to schools. The DBE-Sasol collaboration developed Siyavula Textbooks/Workbooks for Mathematics, Science and Technology for Grade 4–6 and 7–9 learners. These are made available to provinces on print-ready discs, and they have to print for their own schools using their equitable share budget (correspondence with DBE). The ability of resource-poor contexts to print, however, is a question.

Figure 52: Percentage of learners with access to mathematics textbooks and workbooks, by school status



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Figure 53: Percentage of learners with access to science textbooks and workbooks, by school type



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Next, we combined the categories of learners sharing workbooks or textbooks with classmates and those who did not have these resources, in order to establish the association with achievement for those who had their own textbooks and workbooks (Table 27).

Learners who had their own mathematics or science textbook or workbook achieved significantly higher mathematics and science scores than those who shared or did not have workbooks or textbooks.

Table 27: Association between access to textbooks and workbooks, and achievement

	National achievement (SE)	No-fee achievement (SE)	Fee-paying achievement (SE)
Learner access to mathematics textbook			
Access to own copy	397* (2.5)	367 (2.8)	453* (3.6)
Share or do not have	376* (2.7)	363 (2.7)	408* (4.4)
Learner access to mathematics workbook			
Access to own copy	395* (2.3)	368* (2.7)	445* (3.5)
Share or do not have	362* (3.1)	351* (2.7)	400* (8.3)
Learner access to science textbook			
Access to own copy	391* (3.7)	341* (3.8)	466* (5.0)
Share or do not have	347* (3.6)	331* (3.3)	398* (8.1)
Learner access to science workbook			
Access to own copy	393* (3.4)	340* (3.5)	462* (4.0)
Share or do not have	345* (4.0)	331* (3.6)	395* (11.4)

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

8.3. CLASSROOM INSTRUCTIONAL PRACTICES

In order to explain learner achievement, it is important to understand the nature of classroom instruction and educator engagements. The following analyses provide insights into what takes place inside classrooms by reporting on (i) instructional clarity from the perspective of learners and educators; (ii) learner behaviour in classrooms; and (iii) emphasis on science investigations.

Educators' instructional clarity

Classroom instruction and educator engagement are at the core of the learning process (Nilsen & Gustafsson, 2016). An important quality of an effective educator is the ability to use classroom instruction to engage learners, to explain subject content clearly, and to determine learners' understanding of the topic. We report on instructional clarity in classrooms from the perspectives of educators and learners.

Our analysis considers two dimensions of instructional clarity, namely, cognitive activation and a supportive learning environment. Cognitive activation refers to educators' ability to challenge learners cognitively through activities such as evaluation and integrating and applying knowledge to solve problems. Educators can create a supportive learning environment by providing positive feedback, listening, responding to learners' questions, and providing extra help when needed (Nilsen & Gustafsson, 2016).

Table 28 reports on mathematics and science educators' strategies in teaching their classes. In general, the majority of educators reported that they frequently employed these strategies in their mathematics and science lessons. Considering the teaching and learning conditions in classrooms, such positive teaching behaviours suggest that educators may have been providing socially desirable answers.

Table 28: Percentage of learners by educators' rating of their instructional clarity

Elements of Instructional Clarity	Percentage of learners experience of strategy for 'half or more lessons'	
	Mathematics	Science
Cognitive activation		
Ask learners to explain their answers	82	82
Relate the lesson to learners' daily lives	68	81
Ask learners to decide their own problem-solving procedures	67	67
Ask learners to complete challenging exercises	62	59
Bring interesting materials to class	45	59
Supportive learning environment		
Link new content to learners' prior knowledge	93	91
Encourage learners to express their ideas in class	81	83
Encourage classroom discussion among learners	73	69

Source: TIMSS 2019 South African Grade 9 dataset.

The TIMSS questionnaire also asked learners to rate their educators' instructional clarity on a number of statements, to establish the Instructional Clarity Index (Table 29). The rating by learners was slightly lower than that given by the educators. On average, 52 percent of mathematics learners and 53 percent of science learners reported that their educators provided high clarity of instruction. The comparable international average was 46 percent for mathematics and 49 percent for science.

The other low-performing countries also rated their educators highly in terms of instructional clarity. South African learners either provided socially desirable answers or perceived that the teaching experience that they received was a good one.

Table 29: Learners' rating of educators for Instructional Clarity Index for mathematics and science

Elements	Percent of learners who 'agree a lot'	
	Mathematics	Science
My teacher explains a topic again when we don't understand	71	65
My teacher is good at explaining mathematics/science	63	65
I know what my teacher expects me to do	60	59
My teacher does a variety of things to help us learn	59	56
My teacher has clear answers to my questions	52	57
My teacher is easy to understand	49	54
My teacher links new lessons to what I already know	46	47
INSTRUCTIONAL CLARITY INDEX	**52**	**53**

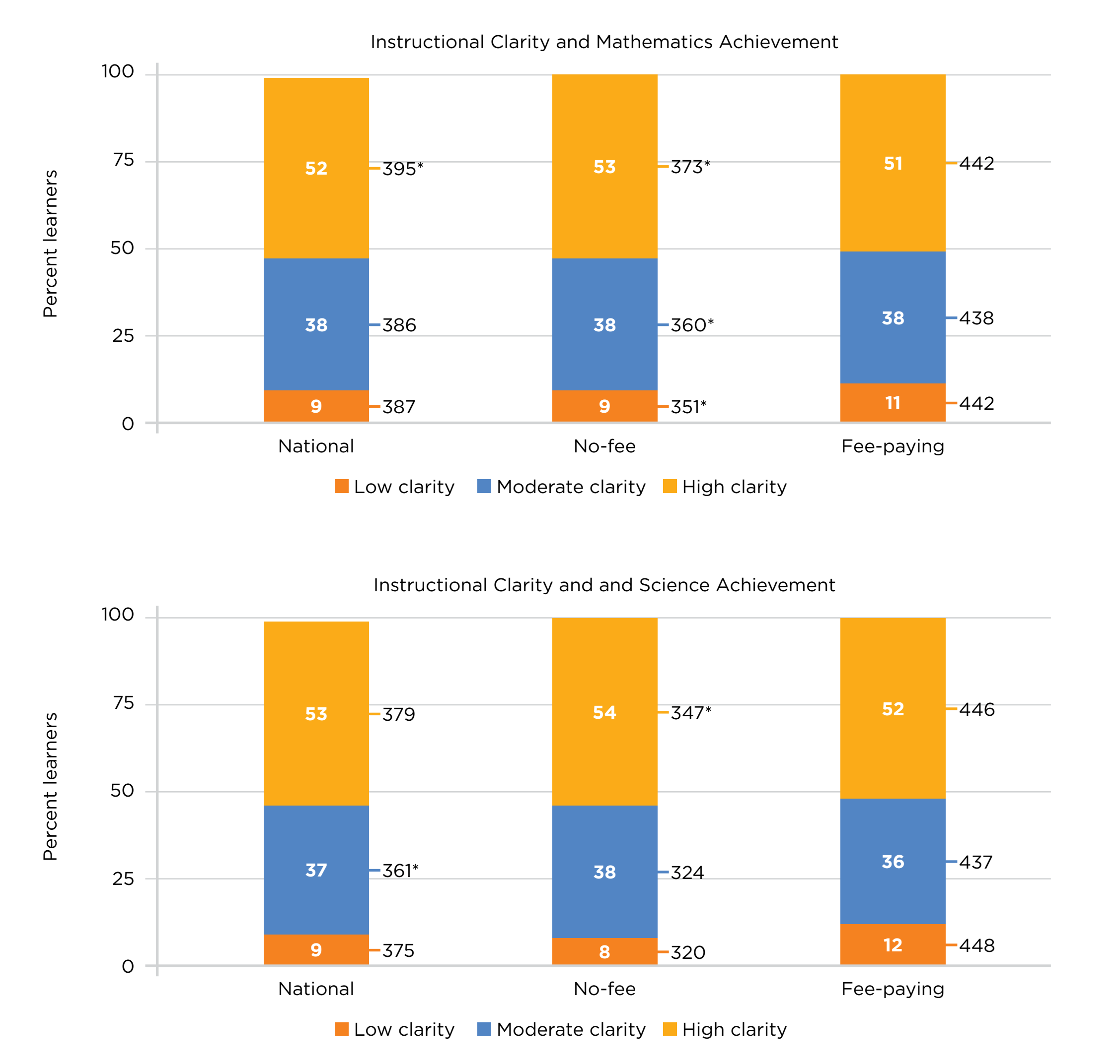
Source: TIMSS 2019 South African Grade 9 dataset.

TIMSS created an *Instructional Clarity Scale* based on learner responses to the seven items[45]. The scale comprised three categories: 1) *low clarity* of instruction, 2) *medium clarity* of instruction, and 3) *high clarity* of instruction. Figure 54 reports on the association between clarity of instruction, and mathematics and science achievement. In terms of the rating of instructional clarity, the results were similar for learners at the national level, and in no-fee and fee-paying schools. Learners who reported high instructional clarity achieved significantly higher mathematics scores than those who reported moderate instructional clarity. Mathematics learners reporting high instructional clarity scored 395 versus 386 for those reporting moderate instructional clarity. In no-fee schools, learners who reported high instructional clarity achieved significantly

45 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *Instructional Clarity Scale* (Page 459 for mathematics and 477 for science).

higher scores than those who reported moderate or low instructional clarity. Also in no-fee schools, learners reporting moderate instructional clarity significantly outperformed learners who reported low instructional clarity. In fee-paying schools, we did not observe any relationship between reported instructional clarity and mathematics achievement.

Figure 54: Relationship between Instructional Clarity and achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Learner behaviour during mathematics lessons

Good classroom management, and having learners pay attention and focus on the lessons, help create a classroom environment conducive to learning. Learners were asked a series of six questions about the frequency of disorderly behaviour during mathematics lessons, including whether learners listened to what the educator said, how often the classroom was too disorderly for learners to work well, and how often educators had to tell learners to follow the classroom rules. Table 30 reports on the percentage of learners who experienced this behaviour in almost every lesson.

Half of the learners reported that the educator had to tell the class to follow classroom rules in almost every lesson, and just over one in four learners experienced different forms of disruptive behaviours in the mathematics classroom almost every lesson.

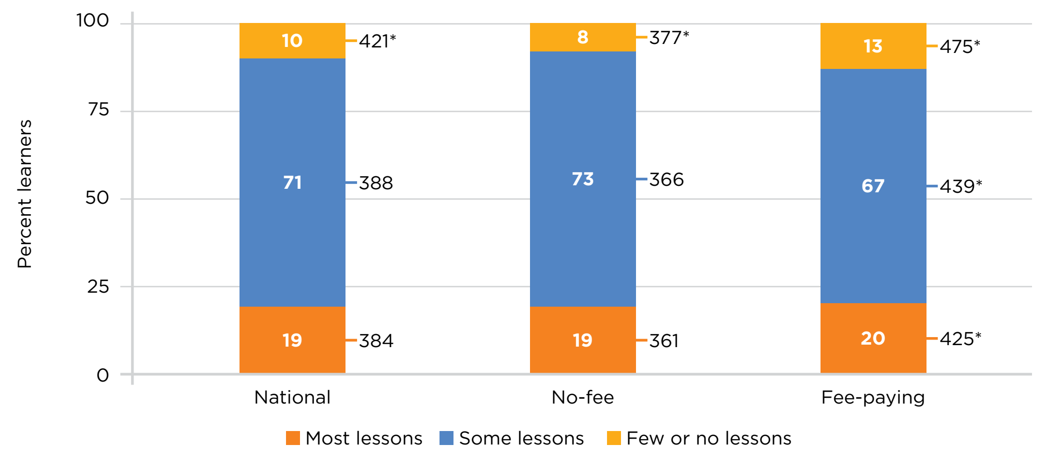
Table 30: Elements that constitute disorderly behaviour during mathematics lessons

Disorderly behaviour during mathematics lessons	Percent learners experiencing the behaviour in 'almost every lesson'
My teacher has to keep telling us to follow the classroom rules	47
My teacher has to wait a long time for learners to quiet down	30
Learners interrupt the teacher	28
Learners don't listen to what the teacher says	30
There is disruptive noise	28
It is too disorderly for learners to work well	25

Source: TIMSS 2019 South African Grade 9 dataset.

These six responses were combined into a *Disorderly Behaviour during Mathematics Lesson Scale*[46]. There is a higher level of disorderly behaviour in South African mathematics classrooms when compared to other countries. Nineteen percent of South African Grade 9 learners experienced disorderly behaviour in most lessons, compared to the international average of 13 percent. Internationally, and in most countries including South Africa, there was a negative association between the frequency of disorderly behaviour and average mathematics achievement. Learners in classes with disorderly behaviour in a few lessons scored 421, in comparison with 384 for learners who experienced disorderly behaviour in most lessons (Figure 55).

Figure 55: Percentage of learners experiencing disorderly behaviour during mathematics lessons, and achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Emphasis on science investigation and experiments

The first aim stated in the Natural Science Curriculum is that learners must 'do' science. Doing science involves conducting investigations, analysing problems, and using practical processes and skills in evaluating solutions. Basic resources to teach science in a practical manner are essential, and schools with a laboratory and/or science equipment are more effective in providing a quality science teaching and learning experience.

Schools with science laboratories

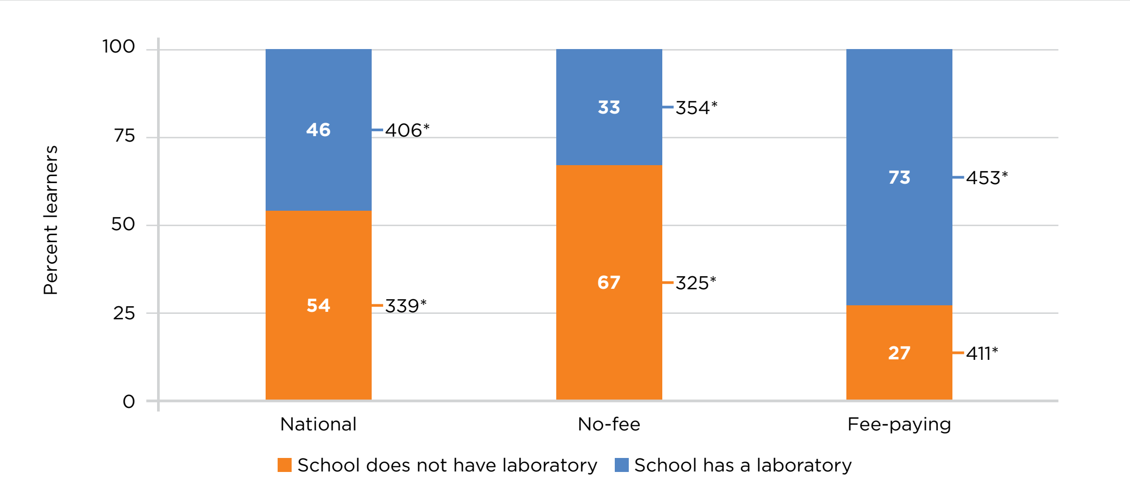
Using principals' responses, Figure 56 reports on the availability of a laboratory *for conducting science experiments* (by the percentage of learners attending schools with laboratories), and the relationship with science achievement.

46 See TIMSS 2019 International Results in Mathematics and Science Report (https://timss2019.org/reports/download-center/) for a description *Disorderly Behaviour during Mathematics Lesson Scale* (Page 363).

Nationally, close to half of the learners were taught in schools that had a science laboratory. However, according to the 2020 National Education Infrastructure Management System (NEIMS) report, only 20 percent of all schools in the country had a laboratory (DBE, 2020c). We were unable to corroborate this with figures for secondary and primary schools.

When the TIMSS 2019 data were disaggregated by school type, one in three learners in no-fee schools and three in four learners in fee-paying schools, attended schools with a science laboratory. Learners in schools with a science laboratory achieved significantly higher science scores (406) than those attending schools that did not have a laboratory (339).

Figure 56: Percentage of learners attending a school with a science laboratory, and science achievement



* Statistically significant achievement difference between categories.

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Instructional activities related to science investigation

Grade 9 science educators were asked how often they conducted certain instructional activities (Table 31) that emphasise science investigation. According to the science educator reports, about half of the learners observed natural phenomena, interpreted data from experiments, and used evidence to support conclusions in at least half of their science lessons. These occurrences are high when comparing with internal consistency (conducting experiments, 44%) and corroborating with other data (e.g. Table 27 of this chapter). This suggests a response bias, with educators perhaps providing more socially desirable responses.

Table 31: Percentage of learners, according to science educators, who were asked to do the following in science lessons

Science Investigation Instructional Activities	Percentage of learners reported to experience science investigation activities in 'half the lessons or more'
Observe natural phenomena and describe what they see	61
Use evidence from experiments or investigations to support conclusions	51
Interpret data from experiments or investigations	49
Conduct experiments or investigations	44
Present data from experiments or investigations	43
Watch me demonstrate an experiment or investigation	41
Design or plan experiments or investigations	36
Do field work outside of class	16

Source: TIMSS 2019 South African Grade 9 dataset.

8.4. COMPUTERS IN EDUCATION AND INSTRUCTION

In the pre-COVID-19 period, educational systems throughout the world invested in digital technology to promote learning. The pandemic, however, placed the spotlight on digital technologies and their importance for improving access to education and learning. Using data collected pre-COVID-19, we report on the access of digital technologies for learning in the home, school and mathematics and science classrooms.

Computers in the home

Around half of the learners reported having access to a computer (or tablet), and 41 percent reported having an Internet connection at home (see Chapter 5). When compared with the findings of the 2019 General Household Survey (GHS), the TIMSS learners may have over-reported the availability of these assets at home. GHS 2019 reported that 23 percent of households had a computer and nine percent had access to the Internet (StatsSA, 2020a).

Learners who reported access to computers at home achieved significantly higher mathematics and science scores than learners without these resources (Table 32).

Table 32: Availability of a computer or tablet at home and achievement

Subject	National			
	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	48	410 (2.7)	52	372 (2.5)
Science	48	400 (3.7)	52	344 (3.3)

Source: TIMSS 2019 South African Grade 9 dataset.

Computer access in schools

The number of computers available for use in Grade 9 classes, as reported by principals, is shown in Table 33. Sixty percent of Grade 9 learners had no access to computers, and a quarter of learners attended schools with more than 20 computers for their use. More learners in fee-paying schools had access to computers than in no-fee schools (35% in no-fee schools versus 49% in fee-paying schools)[47].

Table 33: Percentage of learners with access to computers (including tablets) in Grade 9 classes

	National	No-fee	Fee-paying
0 computer	60	65	51
1-10 computers	6	7	5
11-20 computers	8	9	6
21-30 computers	10	8	14
More than 30 computers	16	12	24

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Computer access and use in classrooms

Mathematics and science educators responded to whether Grade 9 learners had access to computers in their mathematics and science lessons. According to educator reports, 10 percent of learners had access to computers in these lessons (Table 34). Learners who had access to computers for mathematics and science lessons, achieved significantly higher mathematics and science scores than those who did not have access.

While 10 percent of learners had access to computers in class, according to educator reports only five percent of learners were in classes that used computers for instruction.

47 According to the NEIMS 2020 report, 36% of schools have a computer centre and 20% of schools have Internet connectivity for teaching and learning purposes.

Table 34: Percentage of learners with access to computers for Grade 9 mathematics and science lessons, and achievement

Subject	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	9	417* (11.5)	91	388* (2.8)
Science	10	404* (16.9)	90	366* (3.2)

Source: TIMSS 2019 South African Grade 9 dataset.

In the following infographic, we present a summary of the various factors related to classrooms, educators and resources that impact teaching and learning.

8.5. SUMMARY: CLASSROOMS: EDUCATORS, RESOURCES AND INSTRUCTIONAL PRACTICES

Classrooms

Successful learning is likely to be affected by the calibre of educators, the quality of classroom environments and instructional activities, as well as the resources available to support instruction. South African learners enter schools and classrooms with different levels of readiness for learning.

Educator characteristics

The average teaching experience of South African mathematics educators was 14 years and for science educators it was 15 years. Eighty percent of learners were taught by mathematics and science educators who reported that they had at least a Bachelor's degree qualification, compared with 96% of learners internationally. Ninety-one percent of mathematics learners and 86 percent of science learners were taught by educators who reported that they had a subject specialisation.

Educator professional development

Educators attended a high number of professional development activities. The majority of mathematics and science professional development activities related to curriculum, content and assessment. An unexpected finding was the low level of professional development activities related to pedagogy or instruction, a key factor in improving educational achievement. Half the educators attended professional development activities during school hours, a quarter after school and the other quarter on weekends or during school holidays.

Class size and achievement

The average TIMSS Grade 9 class size was 51 learners, with the class size ranging from seven to 140 learners. The average class size in no-fee schools was 56 learners, and only 16 percent of learners were in classes with less than 40 learners. In fee-paying schools, the average class size was 41 learners, and half the learners attended classes with less than 40 learners.

There was a significant difference in the average mathematics and science achievement for learners in classes with less than 40 learners who scored higher than those in classes with more than 40 learners.

Textbooks and workbooks

Learners had better access to mathematics text resources, with 88 percent either owning or sharing a textbook, and 92 percent either owning or sharing a workbook. For science, 20 percent of learners did not have a science textbook and one-third of learners did not have a science workbook. Unfortunately, 17 percent of learners had neither a science workbook nor textbook.

Learners in fee-paying schools had higher access to mathematics and science textbooks and workbooks than learners in no-fee schools. Learners who had their own mathematics or science textbook or workbook achieved significantly higher mathematics and science scores than those who shared or did not have workbooks or textbooks.

Classroom instructional practices and learner behaviour

Classroom instruction and educator engagement are at the core of the learning process. On average, 52 percent of mathematics learners and 53 percent of science learners reported that their educators provided high clarity of instruction. Learners who reported that they experienced high instructional clarity achieved significantly higher mathematics and science scores than those who reported moderate and low clarity.

Good classroom management, and having learners pay attention and focus on the lessons, help create a classroom environment conducive to learning. There was a higher level of disorderly behaviour in South African classrooms with 19 percent of learners reporting that they experienced disorderly behaviour in most lessons, compared to the international average of 13 percent.

Internationally and in South Africa, there was a negative association between the frequency of disorderly behaviour and average mathematics achievement.

Science investigations and experiments

According to the principal reports, half of the learners attended schools with a science laboratory. This translates to one in three learners in no-fee schools, and three in four learners in fee-paying schools.

Learners in schools with a science laboratory (a useful proxy for school resources) achieved significantly higher science scores than those attending schools that did not have a laboratory.

Computers in education and instruction

According to principal reports, 40 percent of learners in South Africa (35 percent in no-fee schools and 49 percent in fee-paying schools) had access to a computer or device that could be used by Grade 9 classes. Educators reported that 10 percent of learners had access to computers to use in the Grade 9 mathematics and science lessons. While 10 percent of learners had access to computers in class, only five percent of learners were in classes that used computers for instruction.

Learners who had access to computers for mathematics and science lessons achieved significantly higher achievement scores than those who did not.

The next section of the report presents a series of multivariate analyses to explore the relationships between key characteristics of where learners live and learn, and their mathematics achievement.

SECTION F

A MULTIVARIATE ANALYSIS OF FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

The preceding chapters have highlighted the broad range of factors related to performance in mathematics and science, showing how achievement varies by the type of school learners attend, the households they grow up in, the availability of resources in both settings and examples of what goes on in each.

These characteristics – school infrastructure, climate and resources, parents' socioeconomic status (SES), proficiency in the language of learning and teaching, learner attitudes and experiences, classroom practices, etc. – do not, however, exist or operate in isolation. Rather, they are interrelated and grouped together in different ways, and so their relationship with achievement reflects how those factors operate together. In short, many of the influences on achievement cluster together and none of them operate in isolation from each other. To get a better understanding of which influences have the strongest association with achievement and, therefore, which potential policy levers might yield the greatest gains in performance, we need to consider how these different factors operate together.

This chapter presents a series of multivariate analyses to explore the relationships between key characteristics of where learners live and learn and their mathematics achievement, how those relationships change when factors are considered together, and to identify the strongest associations with Grade 9 mathematics performance.

CHAPTER NINE

FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

9.1. AN OVERVIEW OF THE APPROACH USED

Building on the previous chapters, which explored the relationships between a number of individual, family and school-level characteristics, and learner achievement in mathematics, the analysis presented in this chapter focuses predominantly on those correlations already shown to be significant. In doing so, we aim to present a parsimonious model of the characteristics associated with mathematics attainment. In other words, when we consider all the measures we have that are associated with achievement simultaneously, which ones matter most? The analysis is presented in three sets of sequential regression models.

Basic associations

The first set of regressions summarises the basic, bivariate and linear associations between each predictor variable and mathematics achievement to gauge the size and strength of each unique relationship. This association is essentially the correlation between two variables, such as language proficiency and achievement, but reports the 'effect' in terms of the average difference in TIMSS mathematics achievement scale points related to each 'level' of change in the predictor variable. The term 'effect' is used for descriptive purposes only and does not imply a causal relationship between variables, but rather is shorthand for describing the association between the variables being considered.

In line with the descriptive analyses summarised in the preceding chapters detailing the size and shape of the various characteristics of the TIMSS sample, the regression results given here are shown in terms of the levels[48] of each predictor variable as already defined – e.g. school quintile; household SES as high, medium, or low; frequency of bullying as never, almost monthly and almost weekly – and report the difference between each level of that variable and a base or 'reference' category.

If this difference reflects genuine differences between the scores of learners in the two groups rather than just chance variation across the two samples, it is considered to be significant.

Grouped associations

The second set of analyses considers groups of characteristics, for example individual-level characteristics, indicators of household SES, factors describing the classroom and educator, to explore in more detail how different sets of influences operate when considered jointly since that is how learners experience them.

Once similar types of factors are considered together, the strength of any particular variable's association with achievement will likely reduce, but this 'grouped' relationship effect will better reflect the actual context the learner experiences. For example, learners with individual access to workbooks are also more likely to have sole use of a textbook. At the same time, these same learners are less likely to be in classrooms where instruction is affected 'a lot' by a shortage of resources. Individually, each of these classroom aspects are important for achievement, but because they are themselves related, when their impact is considered jointly, the relationship between each single contributor and performance will typically be less. By looking at the relative contributions of each factor in a single model, we are better able to understand how different features of each context are related and start identifying which factors matter most.

Full model: Considering all factors together

The final analysis presents a single regression model with all influences on achievement considered together to identify the biggest factors associated with achievement. This last step in our multivariate approach attempts to fully capture the day-to-day lived experience of the individual and the joint impact of the most important

48 We report the results in terms of TIMSS points and 'levels' of each variable rather than using standardised versions of the continuous scale scores to ease interpretation and comparison of the average points score differences observed in the regression model and the relative advantage/disadvantage gained for different groups.

features of the contexts in which they live and learn in order to identify which indicators remain significantly associated with achievement when their influence is considered simultaneously.

For example, school-level characteristics, such as access to resources, are likely to be closely linked to classroom characteristics – individual work and textbooks, mathematics-specific teaching aids – as well as the school's overall quintile ranking. Features of the different context areas are linked together in certain ways and so too are the contexts themselves. Because learning takes place within these intertwined contexts, it is only by understanding their influence altogether that we can properly identify the factors most associated with gains in performance.

Statistical analysis

All statistical analyses were performed using Stata 14.2 (StataCorp, 2015) using the package 'repest' (Avvisati & Keslair, 2014) developed by the OECD, which allows Stata users to analyse OECD and the International Association for the Evaluation of Educational Achievement large-scale international surveys. Repest is a Stata routine that is designed to estimate statistics using replicate weights, thus accounting for the complex survey design of TIMSS in the estimation of sampling variances.[49] The package also allows for analyses of datasets with plausible values (multiply imputed variables) ensuring that correct point estimates and standard errors are reported. Where plausible values are used, the average estimator across plausible values is reported and the imputation error is added to the variance estimator.

9.2. BASIC ASSOCIATIONS: Summarising individual, family and school-level characteristics and their relationship with achievement

The following tables report the results from a series of bivariate regressions between mathematics achievement and measures of the learners' own characteristics, their home environment and school context shown to significantly correlate with each other in the previous chapters. The coefficients show the basic association between each individual variable and attainment without including any other measures in the model. Characteristics are grouped into broad, context-based areas and presented in a single table for ease of presentation.

School quintile

The first panel shows the basic association between school quintile and achievement in mathematics and the coefficient is the average gain in TIMSS mathematics points for learners in each school quintile when compared to those in Quintile 1, the most economically disadvantaged group. These coefficients are the same mean differences in learner scores between the school quintile shown in Chapter 2 which showed that, on average, learners in Quintile 2 schools scored an additional 10 points compared to those in Quintile 1 schools (366 versus 356), and those in Quintile 3 schools scored an additional 14 points (370 versus 356).

In this basic model of association with achievement, the relationship between school quintile and mathematics achievement was very strong.

Table 35: Basic associations between school quintile and achievement

	Coeff.	SE	Sig.
Quintile: (Ref = Q1)			
Q2	10	(5.9)	
Q3	14	(5.2)	**
Q4	51	(8.6)	***
Q5	107	(6.2)	***
Independent	121	(9.1)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

49 Specific commands for TIMSS were written by the package author, Francesco Avvisati at the OECD (personal communication with report author Dr Kathryn Isdale).

Household characteristics

In terms of household characteristics, learners from middle SES homes scored, on average, 63 points lower than those from high SES households, while those in low SES homes scored an average of 84 points lower (See Chapter 5 for further details).

Parents' own educational capital is also a highly significant predictor of achievement: compared to those whose parents had no problems understanding the language of the test, those whose parents sometimes struggled with the language scored 49 points less and where parents frequently struggled, this gap increased to 67 points.

Table 36: Basic associations between characteristics of the household and achievement

Household Characteristics	Coeff.	SE	Sig.
Household SES indicator: (Ref = High)			
Middle	-63	(3.7)	***
Low	-84	(3.9)	***
Parents have difficulties understanding LoLT: (Ref = Never)			
Sometimes	-49	(2.2)	***
Frequently	-67	(2.6)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Individual-level characteristics

Girls scored an average of seven points more than boys. Learners who were overage for the grade scored significantly lower than those who were the correct age, with each additional episode of grade repetition widening this gap. Learner proficiency in the language of the test was strongly related to mathematics performance (See Chapter 5 for further details).

Table 37: Basic associations between characteristics of the individual and achievement

Individual-level Characteristics	Coeff.	SE	Sig.
Girl	7	(2.1)	**
Age bands: (Ref = Correct age)			
Overage by up to 12 months	-50	(2.4)	***
Overage by 12-23 months	-67	(2.8)	***
Overage by more than 24 months	-87	(3.8)	***
Language proficiency: Speak lang. of test at home (Ref = Frequently)			
Sometimes	-54	(3.5)	***
Never	-76	(4.9)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Learner attitudes and experiences at school

Learners' own feelings about their ability in mathematics and its importance were also significantly associated with attainment, with learners who were very confident in their own ability in mathematics scoring significantly higher than those who were somewhat confident or not confident in their ability in mathematics. There were similar relationships for learners valuing mathematics. Learners who were bullied in school did worse in mathematics, with those experiencing monthly bullying scoring, on average, 25 points lower than those who were never or rarely bullied, and those who were bullied weekly scored 61 points lower (See Chapter 6 for further details).

Table 38: Basic associations between learner attitudes and experiences at school and achievement

Learner Attitudes and Experiences at School	Coeff.	SE	Sig.
Learner confidence in mathematics: (Ref = Very confident)			
Somewhat confident	-72	(4.0)	***
Not confident	-92	(4.1)	***
Learner values mathematics: (Ref = Strongly value)			
Somewhat value	-22	(2.1)	***
Does not value	-42	(4.0)	***
Learner is bullied: (Ref = Never or Almost never)			
About Monthly	-25	(2.0)	***
About Weekly	-61	(3.1)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Educator and classroom characteristics

Individual access to a workbook was a key factor in determining achievement: Learners who shared or did not have access to their own workbook scored, on average, 33 points lower than those who did. Similarly, though the strength of the basic association was smaller, individual access to a textbook in class was also significantly associated with mathematics achievement. Where mathematics instruction was affected by mathematics-specific resources shortages, the average difference in the performance of TIMSS mathematics between learners where teaching was and was not affected by resource shortages was 94 points.

There was also a clear association between the number of learners in a mathematics class and achievement: Learners who were in classes with more than 40 learners, on average, scored 55 points lower than those who were in smaller teaching groups.

At the bivariate level, neither educator qualifications nor their subject specialisation in mathematics showed significant relationships with learner achievement.

The clarity with which educators conveyed the content of the mathematics curriculum, however, did have significant implications for both learning and achievement: where there was high clarity of instruction compared to moderate or low clarity, learners scored, on average, an additional nine points in the TIMSS assessment.

Finally, learners in classrooms where disorderly behaviour was reported as present in few or no lessons, scored significantly higher than those where such behaviour was present in some or most lessons (See Chapter 8 for further details).

Table 39: Basic associations between educator and classroom characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.
Learner does not have own Workbook	-33	(2.8)	***
Learner does not have own Textbook	-22	(3.0)	***
Instruction affected by shortage of mathematics resources: (Ref = Not affected)			
Affected	-94	(16.0)	***
Class size: Over 40 learners (Ref = Classes under 40 learners)	-55	(5.2)	***
Educator qualification: (Ref = No degree qualification)			
Bachelors or above	9	(7.0)	
Educator has a mathematics specialisation	4	(7.5)	
Instructional clarity in mathematics lessons (Ref = High)			
Moderate Clarity	-9	(2.3)	***
Presence of disorderly behaviour during Lessons: (Ref = Few/None)			
Some Lessons	-32	(5.1)	***
Most Lessons	-37	(5.9)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Principal and school-level characteristics

Learners in schools located in cities and suburbs significantly outperformed those from small towns and villages by an average of 43 points, and by 67 points for those attending schools in remote rural areas. As with educator qualifications, there was no association between whether a principal was educated to a Bachelor's level or above and achievement in mathematics.

The number of computers in a school can be used as a proxy indicator of resources at the school level. However, the association with mathematics achievement was only significant where the number was high: there was a significant difference in learner achievement in schools that had more than 30 computers compared to those with none at all.

Whether schools have a science laboratory can also be used as a proxy indicator, reflecting access to certain resources, and of being able to create an environment and ethos of practical engagement with learning. Attending a school that had a science laboratory was significantly associated with achievement in mathematics.

In terms of the indicators of the overall school climate: Learners in schools with a strong emphasis on academic success scored an average of 28 points more than those in schools where the emphasis was described as medium; those in schools where principals reported very few problems with discipline showed a 25-point higher score than those where such behaviour was a minor problem, and 47 points more than where discipline levels were rated as moderately to severely problematic. Learners in the safest schools scored, on average, 39 points more than those where safety was moderate and 44 points higher than those in schools perceived to be the least safe (See Chapter 7 for details).

Table 40: Basic associations between principal and school-level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages	-43	(5.6)	***
Remote rural	-67	(5.4)	***
Principal qualification: (Ref = No degree qualification)			
Bachelors or above	3	(14.4)	
Number of computers in the school: (Ref = 0)			
1 to 30	8	(8.6)	
Over 30	47	(8.1)	***
School has a science laboratory	47	(4.6)	***
School's emphasis placed on academic success: (Ref = Strong emphasis)			
Medium	-28	(6.0)	***
School discipline problems: (Ref = Hardly any)			
Minor Problems	-25	(14.5)	†
Moderate to Severe Problems	-47	(13.5)	***
Safe and orderly schools: (Ref = Very safe and orderly)			
Safe and orderly	-39	(8.4)	***
Less than safe and orderly	-44	(9.2)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** p<.001; ** p<.01; * p<.05; † p<.10

9.3. GROUPED ASSOCIATIONS: How do these basic associations fit together in their impact on achievement?

The next step in our analysis to understand the factors affecting mathematics achievement was to examine the nature of the associations when multiple influences are considered together in each category.

Household characteristics

Indicators of SES and the availability of assets in the home continued to predict achievement when considered jointly with our proxy measure of parents' education (parents have difficulty understanding the homework Language of Learning and Teaching (LoLT)). The size of these associations did fall slightly when taken together, indicating some degree of correlation between the two measures – parents with higher education also had higher levels of home assets – but all remained large and strongly associated with attainment.

Table 41: Multivariate associations between characteristics of the household and achievement

Household Characteristics	Coeff.	SE	Sig.
Household SES indicator: (Ref = High)			
Middle	-55	(3.6)	***
Low	-73	(3.7)	***
Parents have difficulties understanding LoLT: (Ref = Never)			
Sometimes	-33	(1.8)	***
Frequently	-51	(2.3)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Individual-level characteristics

When learner gender, age[50] and language proficiency were considered jointly, their individual associations changed, most notably with the advantage observed for girls' achievement in both the descriptive analysis and in the table above reversing. That is, once we took into account age and the other characteristic of the learners, boys performed significantly better than girls by an average of seven points.

Overage learners – those that had previously repeated grades – still achieved significantly lower than those who were the correct age for the grade: those who were overage scored, on average, 56 points less. The importance of proficiency in the test language also remained a highly significant association of achievement when learner age and gender were controlled for, with the size of associations only slightly reduced when considered alongside the other characteristics of the learner.

Table 42: Multivariate associations between characteristics of the individual and achievement

Individual-level Characteristics	Coeff.	SE	Sig.
Girl	-7	(1.8)	***
Age bands: (Ref = Correct Age)			
Overage	-56	(2.4)	***
Language proficiency: Speak language of test at home (Ref = Frequently)			
Sometimes	-48	(3.2)	***
Never	-64	(4.8)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.
Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

50 For greater model parsimony, we reduce the four age categories shown in Table 43 to two: correct age and overage.

Learner attitudes and experiences at school

Both the learners' educational attitudes and their experience of bullying continued to predict achievement when considered simultaneously. Learner confidence in mathematics had a particularly strong relationship with performance in the TIMSS assessment, with those who were somewhat confident scoring 63 points less than those who were very confident, and those not confident scoring 80 points less, even when learners' valuing of the subject and any experience of bullying were taken into account.

Table 43: Multivariate associations between learner attitudes and experiences at school and achievement

Learner Attitudes and Experiences at School	Coeff.	SE	Sig.
Learner confidence in mathematics: (Ref = Very confident)			
Somewhat confident	-63	(3.9)	***
Not confident	-80	(3.9)	***
Learner values mathematics: (Ref = Strongly value)			
Somewhat value	-10	(2.0)	***
Does not value	-30	(3.8)	***
Learner is bullied: (Ref = Never or Almost never)			
About Monthly	-21	(1.9)	***
About Weekly	-54	(3.0)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** p<.001; ** p<.01; * p<.05; † p<.10

Educator and classroom characteristics

When all[51] the educator and classroom characteristics were considered jointly, all of the basic bivariate relationships held, with the relationship of educators having a specialisation in mathematics becoming significant. Once classroom resources, class size, teaching practices and disorderly behaviours were considered, learners in classrooms where educators had a specialisation in mathematics showed a 13-point advantage over those who did not have a specialisation.

With the inclusion of all variables, the strength of some of these associations fell, again reflecting the collinearity (interrelationships) between the characteristics under consideration. However, this provided an indication of which influences have the largest impact on achievement. For example, when learner access to their own mathematics workbook and textbook were considered jointly, the size of the association between having a workbook and achievement was more than four times larger than for having a textbook. Resource shortages and class size continued to be strongly and significantly associated with mathematics achievement.

51 We remove the dichotomous educator qualification from this joint model to explore whether having a specialisation in mathematics is predictive of learner achievement.

Table 44: Multivariate associations between educator and classroom characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.
Learner does not have own Workbook	-21	(2.6)	***
Learner does not have own Textbook	-5	(2.5)	*
Instruction affected by shortage of mathematics resources: (Ref = Not affected)			
Affected	-68	(13.1)	***
Class size: Over 40 learners (Ref = Classes under 40 learners)	-43	(5.2)	***
Educator has a mathematics specialisation	13	(5.7)	*
Instructional clarity in mathematics lessons (Ref = High)			
Moderate Clarity	-7	(2.1)	***
Presence of Disorderly Behaviour during Lessons: (Ref = Few/None)			
Some or Most Lessons	-20	(4.4)	***

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

Principal and school-level characteristics

In the joint model of school-level factors[52], the majority of relationships remained significant despite being somewhat reduced: the spatial location of schools, presence of a science laboratory (proxy for school resources), school discipline problems and perceived school safety levels all had strong and significant associations with mathematics achievement. However, once considered jointly with the other measures of the school context, the relationship between school's emphasis on academic success and learner achievement was reduced considerably, becoming non-significant, again reflecting the collinearity – the inter-relationship – between the school-level characteristics.

Table 45: Multivariate associations between principal and school-level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages	-32	(5.0)	***
Remote rural	-53	(5.8)	***
School has a science laboratory	29	(4.6)	***
School's emphasis placed on academic success: (Ref = Strong emphasis)			
Medium	-5	(4.5)	
School discipline problems: (Ref = Hardly any)			
Minor Problems	-23	(8.5)	**
Moderate to Severe Problems	-46	(8.4)	***
Safe and orderly schools: (Ref = Very safe and orderly)			
Not safe and orderly	-21	(7.7)	**

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** *p*<.001; ** *p*<.01; * *p*<.05; † *p*<.10

52 We do not include principals' qualifications due to the non-significance of the bivariate association and remove the indicator of the number of computers due to concerns about the reliability of how this measure is reported.

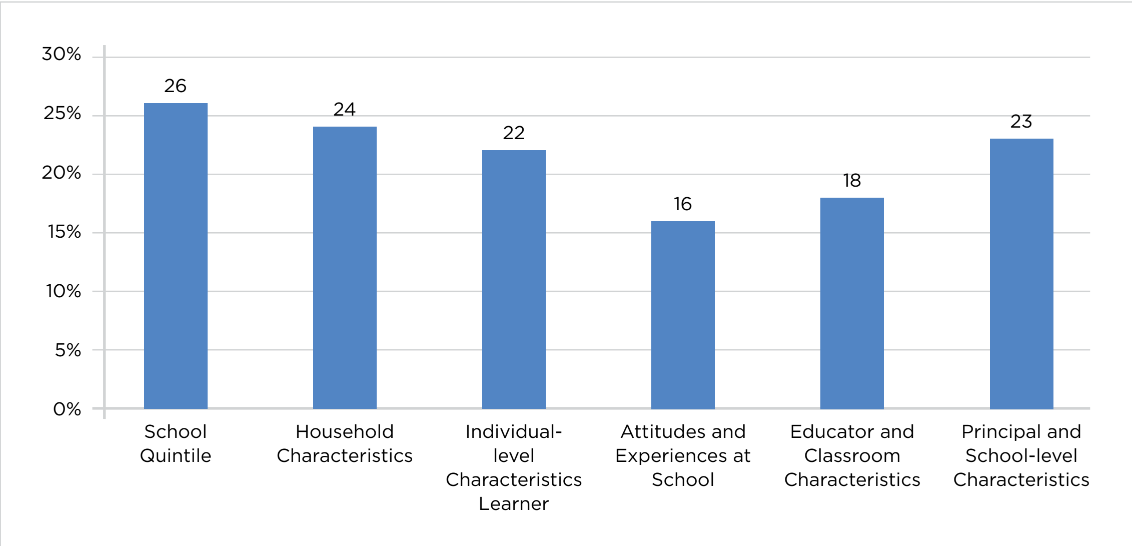
9.4. HOW MUCH OF THE VARIATION IN ACHIEVEMENT CAN THESE CHARACTERISTICS EXPLAIN?

Each of the grouped associations in the aforementioned section was related to learner achievement in mathematics in different ways and by different amounts. One way to compare the contributions of each set of grouped associations (or covariates) on overall performance in the TIMSS assessment is to look at the proportion of variance in achievement that these factors are able to explain, the r-squared value.

Figure 57 shows how much of the variation in achievement each set of covariates was able to account for. As noted earlier, the quintile rank of each school was strongly and significantly associated with mathematics achievement and alone accounted for 26 percent of the variation in performance. The household SES indicators accounted for 24 percent of the variation in achievement, while individual level characteristics (gender, age and language proficiency) accounted for 22 percent. The educator and classroom characteristics accounted for 18 percent of the variance and the principal and school-level characteristics accounted for 23 percent.

Learner educational attitudes and experiences at school explained the least amount of variation in performance – 16 percent – but given that this was based on three indicators: confidence in and valuing mathematics, and having been bullied in school, and it was just two percent less than what was explained by educator and classroom characteristics, these covariates should be considered particularly important factors relating to attainment.

Figure 57: The percentage of variance in TIMSS mathematics achievement accounted for by different blocks of covariates



Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

In the same way that indicators within the different groups of covariates were related to each other, so too were the different blocks themselves: learners from higher quintile schools tended to come from higher SES homes, and more orderly classrooms were more likely to be in schools with better levels of discipline. As such, the proportion of variance accounted for by each set of covariates cannot be thought of as additive, but rather an indication of the relative differences in the size of each contributing area. To understand the total variation these factors explained in mathematics achievement and to identify the strongest associations with TIMSS performance, we need to consider how they would operate in the lives of learners, that is jointly.

9.5. FULL MULTIVARIATE MODEL: Considering all factors together

The final step in our analysis was to enter all the factors associated with achievement into the model simultaneously, exploring which factors remained significant when they were considered jointly, as well as the size of the difference.

Table 46 reports the coefficients – the size of each association – for a single regression model. When taken together these factors explained half – 50 percent – of the variation in learner achievement.

Our multivariate model is deliberately simple, focusing on indicators shown in the preceding chapter (and earlier tables) that were significantly correlated with achievement, and tangible characteristics that are likely to be amenable to change. When all these variables were considered together, most of the associations remained significant. Where associations became non-significant, it indicates that their effect on – or the relationship with – achievement had its impact through another factors, that is, it is mediated by something else.

In the full model with all the other factors considered, only learners in fee-paying schools scored significantly higher than those in Quintile 1 schools indicating that once individual, family, classroom and other school-level factors were controlled for, there was no difference in overall performance for learners in Quintile 1, 2 or 3 schools. Alongside school quintile, household SES and parents' own proficiency in the LoLT (proxy for parental education) also continued to both have strong and significant associations with achievement, confirming again the enduring impact of an individual's circumstances at birth.

For the individual level factors, when all other factors are considered, boys significantly scored around five points higher than girls[53]. On average, overage learners continued to do less well than those of the correct age, and language proficiency remained an important factor explaining mathematics achievement. Interestingly, both measures of learner attitudes about mathematics, as well as any experience of bullying, particularly frequent bullying, continued to significantly influence learners' mathematics performance alongside other family, classroom and school-related factors.

Within the classroom, individual access to a workbook made a significant difference to achievement outcomes: learners without a workbook of their own scored, on average, nine points lower than those who did have a workbook. Resource shortages specific to mathematics continued to be associated with achievement, alongside other indicators of school-level resourcing, including the school's quintile rank and the presence of a science laboratory. Learners in smaller classes scored on average seven points more than learners in bigger classes. Being taught by an educator with a specialisation in mathematics was associated with a 12-point increase in achievement, but clarity of instruction was no longer significant.

Once school quintile and other key factors were accounted for, several of the school-level characteristics remained associated with learner achievement. Learners attending remote rural schools, for example, scored an average of 14 points less than those in cities and suburbs. Learners in better resourced schools, even with quintile status controlled for, scored higher, than those in schools with less resources.

Of particular interest, is the finding that even when school-level discipline problems were taken into account, reports of school safety as well as disorderly behaviour during lessons were significant predictors of achievement. And finally, even with the experience of bullying, the level of disorderly behaviour and school safety considered, learners in schools with discipline problems scored lower than those in schools without such difficulties.

53 We are exploring the results of gender difference in the multivariate further and our analysis will appear in a forthcoming HSRC-TIMSS working paper.

Table 46: Multivariate associations between all factors and achievement

School Quintile	Coeff.	SE	Sig.
Quintile: (Ref = Q1)			
Q2	7	(4.8)	
Q3	6	(4.3)	
Q4	24	(6.2)	***
Q5	43	(6.0)	***
Independent	47	(7.5)	***
Household Characteristics	Coeff.	SE	Sig.
Household SES indicator: (Ref = High)			
Middle	-16	(2.5)	***
Low	-15	(3.0)	***
Parents have difficulties understanding LoLT: (Ref = Never)			
Sometimes	-14	(1.4)	***
Frequently	-28	(2.0)	***
Individual-level Characteristics	Coeff.	SE	Sig.
Girl	-5	(1.5)	***
Age bands: (Ref = Correct age)			
Overage	-33	(2.0)	***
Language proficiency: Speak lang. of test at home (Ref = Frequently)			
Sometimes	-12	(2.1)	***
Never	-22	(3.9)	***
Learner Attitudes and Experiences at School	Coeff.	SE	Sig.
Learner confidence in mathematics: (Ref = Very confident)			
Somewhat confident	-43	(2.7)	***
Not confident	-63	(2.8)	***
Learner values mathematics: (Ref = Strongly value)			
Somewhat value	-9	(1.7)	***
Does not value	-27	(3.4)	***
Learner is bullied: (Ref = Never or Almost never)			
About Monthly	-5	(1.4)	***
About Weekly	-20	(2.5)	***
Educator and Classroom Characteristics	Coeff.	SE	Sig.
Learner does not have own Workbook	-9	(2.3)	***
Instruction affected by shortage of mathematics resources: (Ref = Not affected)			
Affected	-24	(9.4)	*
Class size: Over 40 learners (Ref = Classes under 40 learners)	-7	(2.9)	*
Educator has a mathematics specialisation	12	(5.7)	*
Instructional clarity in mathematics lessons is high:			
Moderate Clarity	2	(1.9)	
Presence of disorderly behaviour during lessons: (Ref = Few / None)			
Some or Most Lessons	-12	(3.8)	**
Principal and School-level Characteristics	Coeff.	SE	Sig.
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages	-7	(4.0)	†
Remote rural	-14	(4.6)	**
School has a science laboratory	11	(3.2)	***
School's emphasis placed on academic success: (Ref = Strong emphasis)			
Medium	3	(3.1)	
School discipline problems: (Ref = Hardly any)			
Minor Problems	-4	(5.4)	
Moderate to Severe Problems	-15	(5.6)	**
Safe and orderly schools: (Ref = Very safe and orderly)			
Not safe and orderly	-5	(3.0)	†
R-squared	**.50**		

Source: Author's own calculations from TIMSS 2019 South African Grade 9 dataset.

Significance levels: *** p<.001; ** p<.01; * p<.05; † p<.10

9.6. FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

South Africa is a country marred by inequities: household resources are vastly unequal across learners and very low compared to international standards, and so we expect the state and the schooling system to help level out the inequality in opportunity. This chapter summarised the influences on Grade 9 learner mathematics achievement, with a particular emphasis on classroom, educator and school-level characteristics that might act as policy levers.

The analysis was presented in a sequential manner, starting with basic associations as a gauge to the relative sizes of these correlations and building up to a comprehensive, yet relatively parsimonious, model of the key factors affecting mathematics achievement. The aim was to highlight how certain relationships might change or weaken in size, when multiple factors are considered together, demonstrate the importance of examining the associations of characteristics jointly, and identify the biggest factors of mathematics achievement.

From the multivariate analysis using a range of characteristics across individual, home and school contexts, a number of key findings emerged:

- An individual's circumstances at birth are critical determinants of life chances, including the schools that learners attend, but schools do have the capacity to positively improve educational outcomes.
- Individual access to workbooks is a key predictor of achievement. Other resources matter too. Increasing resources specific to the teaching of mathematics, as well as access to assets like science laboratories, are all independently associated with learner achievement and important, tangible signals of the prioritisation of excellence in science, technology, engineering and mathematics subjects.
- This analysis confirms previous studies that learners who frequently speak the language of instruction, are regularly exposed to it, and use the language outside of the school, are at an advantage.
- Learners in remote settings also need additional investment and support to help decrease the gaps in attainment and provide fair and equal access to educational opportunities.
- Decreasing class sizes is an important piece in the resourcing puzzle and learners should be taught in smaller overall classes measured by actual headcount rather than via learner–educator ratios.
- Schools need to be safe places to go, not just for learners but for educators too. Unsafe, disruptive classrooms, where bullying is frequent and discipline is a problem, disrupt the learning environment and hinder performance. These aspects of the school environment matter independently of each other and their impact is likely cumulative, compounding poor performance and limiting the opportunities of learners.
- Learners who are overage are more likely to have repeated earlier grades. Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage.
- Learners' own academic beliefs are key factors related to achievement. Being confident in and valuing mathematics are associated with higher performance scores, across the achievement distribution. Learner confidence is part of a virtuous cycle that should be fostered and developed wherever possible: the honest reflection of one's mathematical capability is a recognition of what needs to be done to improve achievements.

In the final part of this report, Section G, we present a set of key findings and implications for the South African education system from the 2019 Grade 9 TIMSS assessment.

SECTION G
RESULTS AND IMPLICATIONS

This TIMSS 2019 Grade 9 report has provided both a contemporary and a 24-year historical perspective of South African mathematics and science achievement. It was written to provide some perspective about how the results of international assessments can be used to provide meaningful national insights.

We have retold the predictable story of advantage begetting advantage at one end of the distribution and compounding disadvantage at the other. We know that the circumstances of one's birth largely determines one's life trajectory and schools one attends. Education and schooling is the responsibility of both the state and society, and educational outcomes are dependent on in-school and out-of-school factors. But schools have the capacity to positively change educational outcomes. In this report we have teased out factors within schools that could promote improved achievements.

This section then brings together the main results from the descriptive, inferential, and multivariate analyses, and furthermore provides policy implications for improving education quality.

CHAPTER TEN

RESULTS, IMPLICATIONS AND RECOMMENDATIONS FROM TIMSS 2019

A. RESULTS FROM TIMSS 2019

Grade 9 mathematics and science performance

1. **Achievement and ability in TIMSS 2019:** Of the 39 countries that participated in TIMSS 2019 at Grade 9, South Africa continued to attain one of the lowest mathematics and science achievements. The South African TIMSS 2019 mathematics score of 389 (SE 2.3) and the science score of 370 (3.1) were an increase of 17 points for mathematics and 12 points for science from the previous TIMSS 2015 cycle. The increase was statistically significant at the 95 percent confidence level for mathematics, and at the 90 percent confidence level for science.

   The TIMSS achievement scores can be used to describe mathematical and science abilities. Forty-one percent of South African mathematics learners had acquired basic mathematical knowledge, and 36 percent of science learners had acquired basic scientific knowledge. It is noteworthy that four percent of mathematics and five percent of science learners reached the higher international achievement benchmarks, meaning that they were able to apply their understanding and knowledge in a variety of complex situations.

2. **Achievement and ability in no-fee and fee-paying schools in TIMSS 2019:** In the socially graded and unequal South African education system, the average mathematics score for learners in no-fee schools was 365 (2.6) and in fee-paying schools it was 440 (3.9). The average science score in no-fee schools was 335 (3.2) and in fee-paying schools it was 442 (5.4).

   This means that the achievement gap between no-fee and fee-paying schools was 75 points for mathematics and 107 points for science. Only one in four learners in no-fee schools, as compared to two in three learners in fee-paying schools, had acquired basic mathematics and science knowledge.

3. **Achievement and ability trends:** From TIMSS 1995 to 2003 there was no statistically significant difference in mathematics and science achievement. From 2003 to 2019, the mathematics and science achievement increased by one standard deviation (104 points for mathematics and 102 points for science). South African mathematics and science achievement averages improved from 'very low' (1995, 1999 and 2003) to 'low' (2011, 2015 and 2019).

   In 2003, only one in ten learners demonstrated that they had acquired basic mathematical and scientific knowledge. This increased to almost four in ten learners in 2019.

   The achievement distribution or achievement inequality (i.e. difference between scores at the 5th and 95th percentiles) decreased from the 2003 to the 2019 cycles: the decrease was from 320 points to 252 points in mathematics, and from 405 points to 341 points in science.

   In the period of the TIMSS assessments, the Gross Enrolment Rate in South Africa increased from 81 percent in 1995 to 83 percent in 2003, and to 101 percent in 2018. Despite the expansion of the education system, and the challenges associated with accommodating and effectively teaching more learners, achievement still improved.

4. **Achievement gaps:** South African achievement continued to be unequal and socially graded. On the one hand, achievement gaps, though decreasing, continued to be linked to socioeconomic backgrounds, gender, spatial location, attending fee-paying versus no-fee schools, and the province within which the school is located. 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 were from the lowest performers. This means that the lowest achieving provinces have improved the most over the long-term period.

5. **Pace of achievement improvement:** South African mathematics and science achievement started from a very low base in 1995, and the improvement has been one of the best out of the set of participating countries. The caution is that the rate of improvement is decreasing and not in line with the developmental goals of the country.

   The average improvement rate for mathematics and science achievement for the 2003 to 2011 period was 7.4 points for mathematics (67 points in total) and 7.1 points for science (64 points in total) per year. However, for the 2011 to 2019 period these figures fell to 4.6 points and 4.8 points per year (an improvement of 37 points for mathematics and 38 points for science).

6. **Gender gaps:** On average, boys were 0.5 years older than girls, suggesting higher levels of grade repetition. There were fewer boys than girls in Grade 9, suggesting more boys dropping out of school, with a four percent difference in the enrolments. The mathematics and science achievement scores were higher for girls than for boys, but when considered with age boys performed better than girls.

Curriculum

7. TIMSS is not a simple assessment. Two-thirds of the TIMSS assessment items required learners to use higher cognitive skills of application and reasoning for success. The South African Grade 9 Curriculum and Assessment Policy Statements had a higher focus on the skills of knowing and solving routine problems, and there was limited emphasis on the skills of applying and reasoning.

8. When compared to the national average scores, mathematics learners performed significantly better in the algebra content areas, while the content of geometry and data and probability proved more difficult for them. In science, learners performed significantly better in the physics content area, while they found the content of biology and Earth science more difficult.

   Mathematics and science learners achieved significantly lower scale scores for knowledge items, whereas their scale scores were significantly higher for mathematics reasoning items and science applying items.

9. Learners performed better on items that required them to select a response (multiple choice question) and had greater difficulty on items where they had to construct a written response. Learners had difficulty in writing coherent sentences and explanations or making an argument.

Home and individual, school and classroom contexts

We analysed the self-reported data from learners, educators, principals and parents in order to identify factors associated with achievement. Similar to other low-performing countries, the South African responses were overly positive and optimistic on some items, which does not match the educational reality.

Home assets, socioeconomic status and individual characteristics

10. The availability of home assets, though improving over time, continued to be unequal. Learners in no-fee schools still had significantly fewer basic, educational, and digital assets than learners in fee-paying schools. According to the Home Asset Scale, 55 percent of learners came from 'low SES' households, 25 percent from 'medium SES' households, and 20 percent from 'high SES' households.

    There is a strong significant association between the SES of learners and their achievement. The household characteristics (assets and parental education) explained 24 percent of the achievement variance. This finding confirms one of the enduring findings in the social science literature that the circumstance of one's birth and parental education predict much of one's educational and life trajectory.

11. Twenty-eight percent of learners (16% in no-fee schools and 51% in fee-paying schools) were reported to be highly proficient in the language of the test. There was a significant association between test language proficiency and achievement. This finding endorses the literature that learners who are fluent in the language of instruction, are regularly exposed to the language, and use the language outside of school, are at an advantage when responding to test items.

12. The average age of South African Grade 9 learners was over a year older than most countries who participated in TIMSS at Grade 8. The average age of girls was 0.5 years less than that of boys, while the average age of learners in no-fee schools was higher than those in fee-paying schools. Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage.

13. Learner attitudes explained a sizeable proportion of variation in achievement. There was a significant association between learners' confidence in their mathematics and science abilities and their achievement, as well as their valuing these subjects and achievement.

Schools and classrooms

14. There is a high achievement variation among schools. The poverty rank of the school (quintile) a learner attends explained 26 percent of the achievement variance. Seven in ten learners in no-fee schools and one in four learners in fee-paying schools were from 'low SES' households. Learners in no-fee schools were almost exclusively Black African, and almost all Indian and White learners, as well as 70 percent of Coloured learners attended fee-paying schools.

15. The educational qualifications of principals, and mathematics and science educators improved over time. Over 80 percent of learners were in schools where the principal, and mathematics and science educator reported that they had, at least, a Bachelor qualification. The majority of educators reported a specialisation in mathematics or science.

    Compared with other countries, South African educators attended the highest number of professional development courses. However, learners' mathematics and science achievement was not associated with the level of tertiary education reported, or the extent of professional development courses that educators had attended.

16. Learners who attended schools in remote areas experienced multiple disadvantages, and they achieved significantly lower mathematics and science scores than learners in areas closer to bigger cities and towns.

17. The climate of the school counts. The majority of South African schools and learners reported a school climate that was unsafe, and had high levels of discipline problems, incidences of bullying and disorderly behaviour in classrooms. All three school climate factors (safe and orderly schools, school discipline and learner bullying) were significantly associated with mathematics and science achievement.

    Learners who were in more safe and orderly schools, with hardly any discipline problems, and who hardly or never experienced any form of bullying achieved significantly higher mathematics and science scores.

    Compared with other countries, South African schools experienced higher levels of disciplinary, safety and bullying problems.

18. The average number of learners in TIMSS Grade 9 classes was 51. The majority of South African classrooms exceeded the number of learners they were designed for, and which are amenable to quality teaching and learning. The average TIMSS class size in no-fee schools was 56 learners (with 84% of learners in a class with more than 40 learners), and in fee-paying schools it was 41 learners (with half the learners in classes with more than 40 learners).

    Learners attending classes with less than 40 learners achieved significantly higher scores than those in classes with more than 40 learners.

19. Resources matter for educational success. Learners achieved higher results in schools with better resources. Overall, 85 percent of all mathematics learners and 54 percent of science learners had their own workbooks. Two-thirds of mathematics learners and half of the science learners had their own textbooks. Learners in fee-paying schools had higher access to mathematics and science textbooks and workbooks than learners in no-fee schools.

    Learners who had their own mathematics or science textbook or workbook achieved significantly higher mathematics and science scores than those who shared or did not have workbooks or textbooks.

20. 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 reported that they did not have access to a computer, and only 10 percent of learners had access to computers in their Grade 9 classes. The lack of computers and connectivity in both homes and schools will further disadvantage South African learners, especially the poor during the time of the coronavirus pandemic.

B. IMPLICATIONS AND RECOMMENDATIONS FROM THE SOUTH AFRICAN TIMSS 2019 RESULTS

The main goal of TIMSS is to assist countries to monitor and evaluate their mathematics and science teaching and learning, as well as their achievement. So, what does the TIMSS results tell us about the health of the South African education system? The Department of Planning, Monitoring and Evaluation's (DPME) Medium-Term Strategic Framework (MTSF) (2019–2024) and the Department of Basic Education's (DBE) *Action Plan to 2024* serve as useful reference points to monitor and evaluate South African performance as well as discuss the implications for improving the quality of education.

These documents outline government's and the education sector's plans to improve education outcomes. The MTSF (2019–2024) outlines five fundamental goals for the country. **The fourth goal is that our schools will have better educational outcomes and be able to read for meaning.** This is accompanied by the three following outcomes, which inform the DBE's *Action Plan to 2024*:

- Improved quality of learning outcomes in the Intermediate and Senior Phases, with inequalities reduced by 2024;
- School physical infrastructure and environment that inspire learners to learn and teachers to teach; and
- Learners and educators feel respected, and learning improves by 2024.

We have shown that conditions in the home explain much of the achievement variance. There are many barriers for learners entering schools – race, socioeconomic conditions and the location of the school – which are strongly correlated with each other and lead to multiple deprivations for the majority of learners. These multiple deprivations exist even before learners enter school.

The societal goal is that the overall home conditions for most learners must improve, so that these learners can start school with less of a disadvantage. The inequality of opportunity must be decreased so that more learners have a chance of success. However, within this context we must look to what schools can do to equalise learning outcomes.

Improved quality of learning outcomes in the Senior Phase, with inequalities reduced by 2024

1. In order to meet the country's developmental objectives, the MTSF (2019-2024) sets the target for the TIMSS Grade 9 average mathematics and science score as 420 for the 2023 cycle. This goal is also embodied in Goal 3 of the DBE's *Action Plan to 2024*. A consequence of the goal of improved learning outcomes is improved grade promotions (Goal 12).

   From 2003 to 2019, the TIMSS mathematics and science scores improved by one standard deviation. In TIMSS 2019, the average mathematics score was 389 and the average science scores was 370. Using the rates of improvement for the previous eight years (4.6 points per year for mathematics and 4.8 points per year for science, shown in Section B of this report) we project a TIMSS 2023 score of 407 for mathematics and 389 for science, without considering the achievement effects of the COVID-19 pandemic. These projected achievement scores fall far short of the MTSF targets.

   In 2019, close to four in ten learners demonstrated that they had acquired the mathematics and science knowledge for Grade 9. Going forward, the DBE should first set a target that half of all learners are to demonstrate these basic competencies in the TIMSS assessments. Reaching and passing the 50 percent mark would be seen as the 'tipping point' for the education system. With more than half the learners having the minimum competencies, it could make the journey of educational improvement less arduous.

   However, the conditions of the coronavirus pandemic and the implementation of social distancing protocols led to losses of teaching and learning time, with projected decreases in achievement scores. COVID-19 amplified all inequalities, and learners in no-fee schools will suffer more learning losses than will learners in fee-paying schools. Taking into consideration the learning losses due to the pandemic, Soudien, Reddy and Harvey (2021) speculated a learning loss of 4.1 percent for 2020. The loss of learning time in schools in 2020 and 2021 will have an effect on the TIMSS 2023 achievement scores.

   Achievement inequalities have been decreasing over the last 24 years. The distributional achievement inequality decreased from the 2003 to the 2019 cycles: by 68 points in mathematics and 64 points in science. The provincial achievement gap over the same period decreased by 12 points for mathematics and by 19 points for science. The achievement gap between no-fee schools and fee-paying schools in 2019 was 77 points for mathematics and 107 points for science.

2. The DBE *Action Plan to 2024* raises the concern about the underperformance of boys in relation to girls and the higher rates of drop-out among boys. We found that the gendered achievement pattern is complex and the interaction between gender and age reverses the advantage to favour boys. We need further exploration to understand these interaction effects.

3. Schools in rural areas experience multiple disadvantages and their spatial location is a significant factor influencing achievement. Changing the conditions of poverty and inequality for homes in rural areas will be a starting point to move towards higher educational outcomes for these learners.

4. The changing South African economy has a demand for high-skilled tertiary education graduates, especially in science, engineering and technology subjects. The increased percentage of Grade 9 learners demonstrating improved abilities in mathematics and science increases the mathematics and science pipeline to the exit level matriculation examination, and further into tertiary studies and the labour market.

   It is noteworthy that 13 percent of mathematics and 15 percent of science learners reached the intermediate achievement benchmark (learners who have and can apply knowledge) level. It is more likely that these learners could achieve success in the exit matriculation examination and proceed to tertiary education to study technical subjects.

5. 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 aiming to increase the number of learners that achieves higher performance. This could be achieved by striving to improve the achievement standards for all learners, as well as implementing advanced enrichment programmes for high performing learners.

6. Our analysis points to the fact that learners who were at the correct age for Grade 9 achieved significantly higher achievements than those who were overage (likely having repeated at least one grade). This suggests that grade repetition, without the provision of additional learning support, does not improve learners' educational outcomes. Since the mathematics and science knowledge structure is hierarchical and dependent on foundational knowledge, learners in Foundation Phase classes must acquire the foundational knowledge and skills before moving to subsequent grades.

School physical infrastructure (and learning resources) and environment that inspires learners to learn and educators to teach

Parents and society expect the state and schools to reduce the inequality of opportunity gradient that characterises South African society. There is a large variation between no-fee and fee-paying schools, as well as within fee-paying schools. In general, learners are differentiated by their SES, and then enter schools that are differentiated by their resource base and learning and teaching cultures. There is a continuity from home to schools, with advantage begetting advantage and the reproduction of society for the majority of learners.

While the MTSF focused on improving physical resources, the DBE's goals largely focus on what happens inside schools and classrooms. In particular, we will look at the implications of TIMSS 2019 results for Goal 15: Ensure that the availability and utilisation of teachers are such that excessively large classes are avoided, Goal 19: Ensure that every learner has access to the minimum set of textbooks and workbooks, and Goal 20: Increase access among learners to a wide range of media, including computers.

7. About 30 percent of schools (mostly fee-paying) are considered as better functioning schools. The learner population profile in fee-paying secondary schools has changed over time to 60 percent African, 20 percent Coloured, 15 percent White and five percent Indian. In order for more learners to succeed in schools, there is a need for more schools to join the group of 'better functioning' schools. The state should focus on whole school development with a key target being to increase the number of well-functioning schools.

8. We found that the average TIMSS class size was 51 learners, with 70 percent of learners in a class with more than 40 learners. On average, learners attending classes with less than 40 learners achieved significantly higher scores than those in classes with more than 40 learners.

We concur with the DBE's Goal 15 that 'the availability and utilisation of teachers are such that excessively large classes are avoided'. No learner should be expected to study in a class with over 40 learners, and no educator should be expected to meaningfully teach a class with over 40 learners.

The first step in achieving lower class sizes would be an audit of how educators are utilised in a school and how lessons are scheduled. Concurrently, as a matter of urgency, in cases where the class sizes are over 60 learners, the state needs to improve the availability of classroom spaces and increase the number of educators that can teach specialist subjects.

9. It is a truism that learners in classes with better resources will achieve better scores than those with less or no resources. Goal 19 states that 'every learner should have access to the minimum set of textbooks and workbooks'. We found that there were fewer science than mathematics learning resources in classrooms. Overall, 85 percent of mathematics learners and 54 percent of science learners had their own workbooks. Two-thirds of mathematics learners and half of the science learners had their own textbooks. Unfortunately, 17 percent of learners had neither a science textbook nor a workbook.

   The results provide clear evidence that learners with their **own** workbooks and textbooks achieved higher achievement scores than learners who either shared or did not have a textbook or workbook. Therefore, as a starting point, all learners must have their own mathematics and science workbook and textbook.

   There were fewer textbooks and workbooks in no-fee schools than in fee-paying schools. Distributing more textbooks and workbooks, especially to no-fee schools, should be immediately tackled, as this would contribute to improved performance levels.

10. While Goal 20 aims to increase learner access to a wide range of media, including computers, the reality is that access to computers in homes and schools is low. Only 10 percent of TIMSS learners had access to computers in their Grade 9 classes. Access to computers and Internet connectivity will be an expensive endeavour and may require funding through public–private partnerships.

Learners and Educators feel safe and respected, and learning improves by 2024

Our starting point is that education is a societal matter involving a number of stakeholders. There are conditions outside the school that need to be in place to facilitate learning within schools; for example, learners coming from homes that have basic assets and resources. The community and society surrounding learners' homes and schools should be safe and free of crime. Again, we have to look at what can be done inside schools to improve learning outcomes.

11. As we note in Point 17 earlier (under 'Schools and classrooms'), compared to other TIMSS participating countries, South Africa reported the highest percentage of unsafe schools, ill-discipline in schools, disruptive behaviour in classrooms and incidences of bullying. The climate of the school counts for learners and educators to feel safe and respected, and school climate factors have a significant association with achievement.

    The poor school climate reflects what happens in the communities surrounding the schools. School climate has an impact on the health and well-being of learners and the staff at a school, as well as teaching and learning, and consequently learning outcomes. The poor school climate and the need for safe schools is not prioritised in the MTSF (as an intergovernmental priority) or the DBE's *Action Plan to 2024*, although the DBE has published the National School Safety Framework (2016) to support schools on school climate matters.

12. Educator qualifications and knowledge are key factors (under the right conditions) that are associated with enhancing mathematics and science learning. According to educator reported qualifications, over 80 percent of learners were taught by educators with at least a degree qualification and specialist knowledge. Furthermore, South African educators reported one of the highest levels of attendance at professional development courses. However, the achievement results of learners did not resonate with the reported qualifications. We are unable to get an authoritative picture on educator qualifications, and the mathematics and science knowledge and competencies of educators. We would recommend an audit of educator qualifications and subject matter knowledge to provide an up to date and accurate understanding of this important factor.

13. Two-thirds of the TIMSS assessment items demanded higher level cognitive reasoning. The South African Curriculum and Assessment Policy Statements (CAPS) 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. We must raise the bar of learning expectations from educators and learners. In our view, the CAPS cognitive levels should set a path to incrementally decrease the proportion of items at the knowing level, and to incrementally increase the proportion of items at the applying and reasoning levels.

14. Another strategic intervention is to improve writing skills. South Africa has a national reading strategy to promote reading. We recommend that the strategy be expanded to become a reading and writing strategy. This will improve learners' ability to write a sentence or explanation and construct a coherent argument.

15. An interesting finding from the study relates to non-cognitive influences, e.g. self-reflection of ability. Learners who had high confidence in their ability achieved higher scores. In this bidirectional relationship, the honest appraisal by learners of their ability to learn mathematics and science could be the start of a conversation about the effort that learners need to put into the learning process, and the support they require, in order to improve their achievement.

IN CONCLUSION

The South African education system has been slowly building and strengthening, but it is still a fragile system. The coronavirus pandemic has dealt the system a major blow: one that it may take years to recover from.

In order to improve education levels, the state must continue with intentional and targeted programmes aimed at decreasing the inequality of opportunities through interventions targeted at improving home and school conditions.

Improving education quality and addressing educational inequalities requires a multipronged approach that includes parents, learners, educators, and educational leadership. Such an approach must focus on building schools as institutions with better infrastructure, stronger leadership, more conducive learning environments, and cultures of valuing education and learning. In addition to having physical resources, principals, educators and learners must focus on instilling a vibrant learning culture within schools. Educators and learners must be in school on time and ready to teach and learn, available resources should be used optimally, and all school stakeholders need to assume personal responsibility and accountability.

As is the case with nearly all research investigating the influences on learner achievement, there is no one 'silver bullet' that will fix low performance, remediate years of social imbalance throughout the system, and penetrate the indelible association between one's circumstances at birth and economic and social outcomes, but these results, like those of previous TIMSS studies, highlight that there are many areas that can and must be improved upon.

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ANNEXURE 1: TIMSS DESIGN AND METHODOLOGY

In Chapter 1 of this report, we discussed the TIMSS Conceptual and Assessment Frameworks, the Achievement and Contextual questionnaires, as well as the South African TIMSS sample. In this section we provide more details on logistical and administrative aspects of the study[54].

The main stages in the design and planning for TIMSS are discussed as follows:

- Pre-administration: Translating and preparing assessment instruments and contacting schools;
- Field testing on instruments;
- Main administration of the TIMSS 2019 assessments;
- Scoring of constructed responses; and
- Creating the TIMSS 2019 data files.

Translating and preparing assessment instruments

The HSRC adapted (for example by changing names and terminology like 'gas' to 'petrol') the assessment instruments for South Africa, as well as translated them from English to Afrikaans in preparation for the 2019 assessment administration. These adaptations and translations were documented using the National Adaptations Forms which are verified by the International Association for the Evaluation of Educational Achievement (IEA) to assess if the national adaptations are likely to impact the ability to produce internationally comparable data. Once verification was complete, the HSRC assembled the achievement booklets and contextual questionnaires using Adobe® InDesign® software, and print-ready copies of the instruments were sent to the TIMSS and PIRLS International Study Center for layout verification and a final review of the national adaptations.

Field testing of instrument

In July 2018, the TIMSS test administration was piloted at four schools: two in KwaZulu-Natal and two in Gauteng. Approximately 500 learners participated in the field test which served as a dress rehearsal for the main survey. Through the field test and the data gathered from the various instruments the research team was able to:

- Determine how well items worked;
- Measure the validity and reliability of the various questionnaire scales/indices; and
- Develop a risk mitigation plan for any problems that may occur.

Contacting schools

Pre-administration contact with schools was extremely crucial and allowed the HSRC to

- Obtain permission from the principal to conduct the study;
- Obtain class information (to randomly select a class during sampling);
- Obtain class lists with learner information; and
- Arrange appointments with the schools to administer the study.

The provincial coordinators, from the provincial departments of education, assisted the HSRC to obtain school and class information. The gathered information was entered into the *Within-school Sampling Software* (WinW3S) which was used to sample classes.

Main administration of TIMSS 2019

Consistency across countries is key and the international TIMSS team thus developed a test administrator manual, as well as two basic procedures to guide countries through the data collection phase.

54 The TIMSS 2019 Australia report (Volume I) was also consulted (Thompson, Wernert, Rodrigues & O'Grady, 2021).

Test administrator manual

The Test Administrator Manual detailed the procedures which had to be followed when administering the achievement booklets and Learner, School and Educator Questionnaire. This was a comprehensive document that provides details about preparing for each assessment, completion of the Student Tracking Form and the Test Administration Form, the timing of the testing sessions, correct procedure, and how to administer the assessment. The latter included the instructions to learners as a script that was to be read-out by the test administrator.

Administration of the main survey

The main survey was administered by an external data collection company with relevant qualifications and experience in the field of data collection. The survey was administered in schools in August 2019. The HSRC worked closely with the DBE and provincial coordinators to ensure that the study was successfully administered.

Monitoring the quality of the survey administration

Quality assurance of the fieldwork allows for valid learner achievement comparisons between and within countries. Thus, 10 percent of the sampled schools were randomly selected and senior HSRC researchers served as National Quality Control Monitors (NQCM) to observe the TIMSS administration process. The NQCM followed the National Quality Control Monitor Manual and completed a Classroom Observation Record for each school. This form was organised into the following four sections:

- Documentation of the TIMSS testing session;
- Summary observations of the TIMSS testing session;
- Learner Questionnaire administration; and
- Interview with the Test Administrator.

In addition, the international TIMSS team selected and trained an International Quality Control Monitor who monitored the administration process in 30 South African schools. This process was independent of the HSRC.

Scoring the constructed response items

TIMSS assessment items comprised multiple-choice and constructed-response (open-ended) items. The constructed-response items were scored by hand and hence the reliability and validity of scoring was critical to the quality of the assessment results. In order to achieve this, the IEA provided training, comprehensive scoring guides, and scoring procedures to country participants. The HSRC employed and trained educators and university students to conduct the scoring. As a quality control measure, eight percent of the learner achievement booklets were marked twice by independent scorers to provide a measure of consistency. This is referred to as reliability scoring.

Qualified and experienced moderators were responsible for moderating 25 percent of the scored achievement booklets on an ongoing basis for maintaining accurate and consistent scoring throughout the process. The HSRC staff supervised the scoring and moderation activities, and ensured that moderation and scoring proceeded as planned, information was recorded properly, and all procedures understood.

All countries who participated in TIMSS 2019 were requested to participate in the Trend Scoring Reliability Study (TSRS) and all TIMSS 2019 countries in the Cross-country Scoring Reliability Study (CCSRS). The actual scoring for TSRS and CCSRS was conducted via an online scoring system. The trend reliability scoring blended in with the main scoring procedure, while the cross-country reliability scoring was completed at the end of all other TIMSS 2019 scoring activities.

Creating the TIMSS 2019 data files

Data entry

The first step was to enter data collected in the TIMSS 2019 survey into data files with a common IEA format. This format used an international predefined codebook which was adapted by the national center data managers to reflect the previously approved adaptions made to the background questionnaires. The data entry software used was Data Management Expert (DME). The following data files were used during data entry:

- Learner Background Data File;
- Learner Achievement Data File;
- Educator Questionnaire Data File with separated files for mathematics and science educators; and
- School Data File.

A data capturing error rate of one percent was acceptable for all contextual data and 0.1 percent for assessment data. As with all previous TIMSS cycles the HSRC submitted data to the IEA with a zero percent error rate. In order to achieve these standards, data were double-captured and stringent procedures were followed during data processing.

Data Processing

Data processing occurred in three phases. The first phase was performed by using the DME software which included four steps as follows:

- Unique ID check – Check for and list duplicate ID's in the datasets;
- Validation check – Check for all wild codes and out of range values;
- Double punching check – Compare data for agreement between first and second capture; and
- Record consistency check – Check inconsistent records across datasets.

The second phase involved updating the WinW3S database with information obtained from the test administration and learner tracking forms as received from data collection.

In the third phase, the DME and WinW3S databases were merged to address the next level of data anomalies. Once these phases were completed, data were exported for submission to the IEA for the final phase of data processing.

The IEA remained in constant contact with the country Data Managers at the HSRC once the final stage of cleaning had commenced. This was to ensure that any additional data related queries the IEA-DPC were solved by the HSRC in a timely fashion once physical instruments had been checked.

ANNEXURE 2: MATHEMATICS AND SCIENCE CURRICULA

Mathematics Curriculum

Learners are introduced to numeracy from Grade R, the reception year, and remains a key subject throughout the schooling years. The CAPS for Grade 7 to 9 outlines mathematical skills a learner should acquire and the content areas covered in the curriculum.

Mathematical skills:

- Developing the correct use of the language of mathematics;
- Developing number vocabulary, number concept, and calculation and application skills;
- Learning to listen, communicate, think, reason logically and apply the mathematical knowledge gained;
- Learning to investigate, analyse, represent and interpret information;
- Learning to pose and solve problems; and
- Building an awareness of the important role that mathematics plays in real life situations including the personal development of the learner.

Content areas:

- Numbers, operations and relationships;
- Patterns, functions and algebra;
- Space and shape (Geometry);
- Measurements; and
- Data handling.

Science Curriculum

South African learners are first introduced to the Natural Sciences and Technology subject in Grade 4. From Grade 7 onward, learners are taught Natural Sciences as a subject. South Africa follows an integrated science curriculum that is set out in the CAPS document (DBE, 2011b). The CAPS sets puts the aims for natural sciences and the content areas covered in the curriculum.

Aims – Learners should:

- Do science (investigations, analyse problems, use practical processes and skills in evaluating solutions);
- Know the subject content and be able to apply it in new contexts; and
- Understand the uses of natural science and indigenous knowledge in society and the environment.

Content areas:

- Life and living;
- Matter and Materials;
- Energy and Change; and
- Planet Earth and Beyond.

ANNEXURE 3: NON-COGNITIVE FACTORS IN THE CAPS DOCUMENTS

The South African Curriculum and Assessment Policy Statements relating to non-cognitive outcomes for mathematics and science.

- Confidence and competence to deal with any mathematical situation without being hindered by a fear of mathematics (p. 8);
- An appreciation for the beauty and elegance of mathematics (p. 8);
- A spirit of curiosity and a love for mathematics (p. 8);
- Recognition that mathematics is a creative part of human activity (p. 8); and
- Learners can gain (science) skills in an environment that taps into their curiosity about the world, and that supports creativity, responsibility and growing confidence (p. 10).

The South African TIMSS 2019 Grade 9 Results: Building Achievement and Bridging Achievement Gaps

The TIMSS 2019 Grade 9 study was administered in August 2019 by researchers at the Human Sciences Research Council, in collaboration with the Department of Basic Education and the International Association for the Evaluation of Educational Achievement. The TIMSS 2019 cycle was the sixth in which South Africa has participated since 1995, generating a 24-year dataset over which trends can be measured. TIMSS 2019 collected learner achievement data in the core subjects of mathematics and science, as well as contextual information from learners, educators and school principals which enabled the exploration of factors that are associated with Grade 9 learners' achievement.

This report highlights how the results of international assessments can be used to provide meaningful insights at the national level. We analysed the South African data from an achievement and achievement gaps perspective. The findings presented in the report are based on descriptive and inferential analysis of the TIMSS data, and provide insights into learner achievement, as well as aspects of learners' home environments, and the school and classroom contexts within which teaching and learning take place. The report concludes with key findings and implications for the senior phase of the South African education system.

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