The South African TIMSS 2019 **Grade 5 Results**

Building Achievement and Bridging Achievement Gaps

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

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Dr Vijay Reddy
TIMSS National Research Coordinator
Human Sciences Research Council

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

CAPS	Curriculum and Assessment Policy Statements
CCSRS	Cross-country Scoring Reliability Study
CSG	Child Support Grant
DBE	Department of Basic Education
DME	Data Management Expert
DPME	Department of Performance Monitoring and Evaluation
ECD	Early Childhood Development
EMIS	Education Management Information Systems
GHS	General Household Survey
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
NQCM	National Quality Control Monitor
OECD	Organisation for Economic Co-operation and Development
PAM	Personnel Administrative Measures
PIRLS	Progress in International Reading Literacy Study
PV	Plausible Value
RSA	Republic of South Africa
SE	Standard Error
SEACMEQ[1]	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SES	Socioeconomic status
SGB	School Governing Body
StatsSA	Statistics South Africa
TIMSS	Trends in International Mathematics and Science Study
TSRS	Trend Scoring Reliability Study
WinW3S	Within-school Sampling Software

1 Previously referred to as SACMEQ.

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.

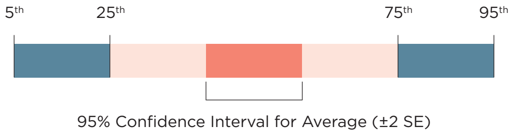
UNDERSTANDING HOW LEARNERS WERE ASSESSED

Less difficult mathematics achievement instrument: South Africa was one of eleven countries that administered the less difficult mathematics assessment (the others were Albania, Bosnia and Herzegovina, Kosovo, Kuwait, Montenegro, Morocco, North Macedonia, Pakistan, the Philippines and Saudi Arabia). This version included some items that were less difficult, while the remainder of the items were the same as in the regular version. An essential aspect of the less difficult mathematics assessment is that the learner achievement results are reported on the same TIMSS achievement scale as the regular mathematics assessment, so that results are comparable regardless of the version of the assessment the learners have taken.

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 5th percentile of the distribution is 200, this means that five 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 5th to the 95th percentile with the confidence interval shown as well (see diagram that follows). 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 first blue section of the bar covers the range between the 5th and 25th percentiles. The first light coral section shows the range of scores between the 25th 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 coral section represents the scores between the upper limit of the confidence interval and the 75th percentile, and the blue section shows the scores between the 75th and 95th 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 percent 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 statistically significant it means that the difference is unlikely to be due to chance. We used the t-statistic for significance testing and report findings at the 95 percent confidence level.

Standard error: The standard error (SE) gives us an estimate of where the true achievement lies. 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 5 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 that 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. 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.

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 5 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, where learners were assessed at the fifth grade, participated in TIMSS 2015, assessing mathematics; and in TIMSS 2019, assessing both mathematics and science. Participation in TIMSS allows countries to evaluate their learners' achievement and compare their national achievement 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.

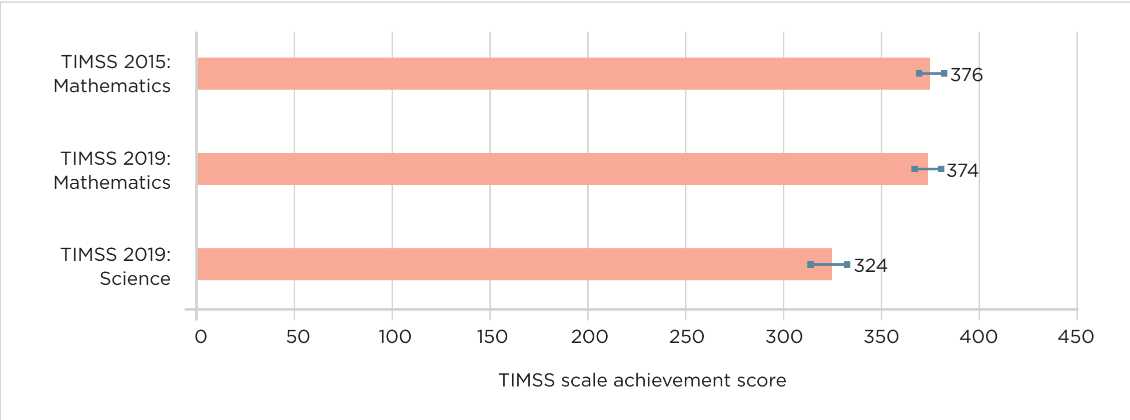
In October 2018, we collected achievement and contextual data in 297 schools across the nine provinces from 11 891 learners and their parents or caregivers, school principals, and mathematics and science educators. The results of the TIMSS 2019 Grade 5 study are presented in this report.

MATHEMATICS AND SCIENCE ACHIEVEMENT, ACHIEVEMENT TRENDS AND GAPS IN THE INTERMEDIATE PHASE

In TIMSS 2019, South African Grade 5 learners achieved an average achievement score of 374 (SE 3.6) on the mathematics assessment and 324 (SE 4.9) on the science assessment[2]. The results also showed that, in this cycle, 37 percent of mathematics learners and 28 percent of science learners had acquired the basic subject knowledge and skills for their grade.

South Africa's participation in the TIMSS 2015 and 2019 cycles at Grade 5 also provides a trend measure of mathematics achievement in the Intermediate Phase. The difference in the average mathematics scale score of 376 (3.5) in TIMSS 2015 and 374 (4.7) in TIMSS 2019 was not statistically significant. The Grade 5 trend results are perplexing as the Grade 9 TIMSS mathematics scores significantly increased over the same period.

The figure below illustrates the TIMSS 2015 and 2019 mathematics scores and TIMSS 2019 science scores, together with the confidence interval.



2 The standard error (SE) gives us an estimate of where the true achievement lies.

There was very high variation in the mathematics and science achievement scores. The achievement difference between the 5th and 95th percentiles (i.e. distribution inequality) was 330 points for mathematics and a higher 434 points for science.

As in the Senior Phase (Grade 9), South African achievement in the Intermediate Phase continues to be low, highly unequal and socially graded. Achievement gaps continue to be linked to learners' socioeconomic background and gender, the spatial location of the school and the school type (fee-paying versus no-fee), learner proficiency in the language of the test, the extent of overage learners and the province where the learner lives and attends school.

This confirms the well-known narrative that advantage begets advantage at one end of the distribution and compounding disadvantage at the other end.

THE MATHEMATICS AND SCIENCE CURRICULUM AND ACHIEVEMENT

Ninety percent of the TIMSS Grade 5 mathematics content and 80 percent of the science content was reported to have been taught in the South African curriculum before learners took the assessment.

TIMSS is not a simple assessment, with approximately 60 percent of the assessment items requiring learners to use higher cognitive skills of application and reasoning. The South African Grade 5 Curriculum and Assessment Policy Statement 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. The mathematics scale score for knowledge and applying items was the same as the national average score, while it was significantly lower for reasoning items.

In relative terms, science achievement was lower than mathematics achievement with fewer science learners (28%) than mathematics learners (37%) acquiring the knowledge and skills for the grade. Science achievement was much lower for learners in poorer home and school environments due to factors such as a limited proficiency in the test language, poor teaching, and learning in poorly resourced environments.

Learners performed relatively better in items requiring them to select a response (multiple choice items) as they had difficulty answering items requiring them to coherently write descriptions or explanations.

INDIVIDUAL CHARACTERISTICS AND ACHIEVEMENT

The learner characteristics of gender, age and proficiency in the language of the test explained 16 percent of the achievement variance.

We found that one in four learners (30% in no-fee schools and 19% in fee-paying schools) were overage for Grade 5. Learners who were the correct age for the grade achieved significantly higher achievement scores than those who were overage.

Just over one in three learners (one in four in no-fee schools and one in two in fee-paying schools) spoke the language of the test at home. 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 in the bivariate analysis, but with an interaction between gender and age, the achievement difference was no longer significant.

THE HOME ENVIRONMENT, EARLY LEARNING, AND ACHIEVEMENT

The socioeconomic conditions in which learners live and learn explained 21 percent of the achievement variance. About a quarter of South African households were categorised as high socioeconomic status (SES), a quarter as medium SES and half as 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 one's educational and life trajectory.

A quarter of South African parents or caregivers reported that they often engaged their children in early literacy and numeracy tasks at home, and these learners achieved significantly higher TIMSS mathematics and science scores. Learners whose parents or caregivers rated their literacy and numeracy school readiness skills highly achieved higher mathematics and science scores than those who were rated lower.

Close to half the learners' parents were able to assist them with homework regularly as they could understand the language and content of the homework. There was a significantly positive association between the extent to which parents were able to assist learners with their homework, and their mathematics and science achievement.

Ninety-two percent of Grade 5 learners had attended Grade R classes and 68 percent had at least two years of preschool engagements. Learners attending two years of preschool achieved significantly higher scores than those attending for only one year.

THE SCHOOL AND ACHIEVEMENT

There was a high achievement variation among schools. The poverty rank of the school (quintile) a learner attended explained 30 percent of the achievement variance. Two-thirds of learners in no-fee schools came from low SES households.

> 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.

Many South African schools and learners reported a school climate that was unsafe, with 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

Educator and classroom characteristics explained 20 percent of the achievement variance.

It is clear from the results that resources matter for educational success. Learners achieved higher scores in schools with better resources. Learners having their own workbook was significantly associated with higher mathematics and science achievement. Overall, 83 percent of mathematics learners and 58 percent of science learners had their own workbooks.

The number of learners in a class matter. The average TIMSS class size was 44 learners (47 learners in no-fee schools and 38 learners in fee-paying schools). Fifty-seven percent of TIMSS Grade 5 learners were taught in classes with more than 40 learners. Learners in 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 in their lessons achieved significantly higher on the mathematics and science assessments.

LEARNER ATTITUDES TO MATHEMATICS AND SCIENCE

An interesting finding relates to learner attitudes towards mathematics and science, and their achievement. Positive attitudes and higher achievement go hand in hand, with each mutually reinforcing the other. Learner attitudes explained 20 percent of the achievement variation.

Learners who liked learning mathematics and science, and had a positive self-reflection of their mathematical and scientific abilities (i.e. confidence in learning), achieved higher scores.

IMPLICATIONS AND RECOMMENDATIONS FROM THE TIMSS RESULTS

While an individual's circumstance of birth remains a critical determinant of their subsequent educational and life trajectory, schools and classrooms still have the capacity to positively improve educational outcomes. There is wide recognition of the importance of building solid knowledge and skills foundations in the earlier years of schooling. Since mathematical and science knowledge acquisition is hierarchical in nature, subsequent learning is dependent on prior knowledge. Thus, we highlight five high-level recommendations, based on the TIMSS 2019 Grade 5 results, to improve educational outcomes in South Africa.

1. We were perplexed that South African Grade 5 mathematics scores did not change between the TIMSS 2015 and 2019 cycles. Thus, it is highly unlikely that the country's achievement scores will improve enough to achieve the Medium-Term Strategic Framework's (MTSF) 2019–2024 target score of 426 points in TIMSS

2023. To understand why there was no improvement in the Intermediate Phase, we recommend a **review of the primary school sector**, including a focus on issues such as support provided to primary schools in comparison to secondary schools; the effectiveness of interventions in Foundation Phase teaching and learning; the nature of teaching, learning and assessments in primary schools; and educators' subject knowledge and their teaching allocation (timetabling) in schools.

2. **Prioritise the first 1 000 days of formal learning, i.e. Grades RR, R and 1**, to plant strong educational roots and build solid foundations. All children must receive at least two years of pre-school education. Early learning must focus on both access to, and high quality, learning experiences in the first 1 000 days of formal learning. Children must be in cognitively rich and stimulating environments that focus on first language development and reading with meaning, basic computational skills and writing simple sentences. Learners must demonstrate proficiency in reading, writing and computation before progressing to the next grades.
3. **Increase the number of well-functioning schools.** About 30 percent of schools (mostly fee-paying) are considered as better functioning schools. The state must focus on whole school development with a key target being to increase the proportion of well-functioning schools so that schools can play the equalising influence role. Learners in no-fee schools depend on quality school inputs to improve educational outcomes. The whole school development focus must be on improving learning infrastructure; improving school climate by encouraging greater emphasis on academic success and making schools safer places for learners and educators; and improving instructional clarity in classrooms.
4. **Resource availability and how it is used matters.** In the short term, all learners must have their own mathematics and science workbooks, especially in remote rural schools. Decreasing class sizes is also an important piece of the resourcing puzzle: learners should be taught in smaller classes with less than 40 learners. The longer-term strategic interventions that are needed include increasing access to computers and Internet connectivity, and the availability of science laboratories and equipment.
5. Pay attention to building both learners' mathematics and science **knowledge, as well as the non-cognitive dimensions** of liking and being able to honestly appraise their abilities in these subjects. In the mutually reinforcing relationship between achievement and attitudes, 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 from homes and schools, to improve their achievement.

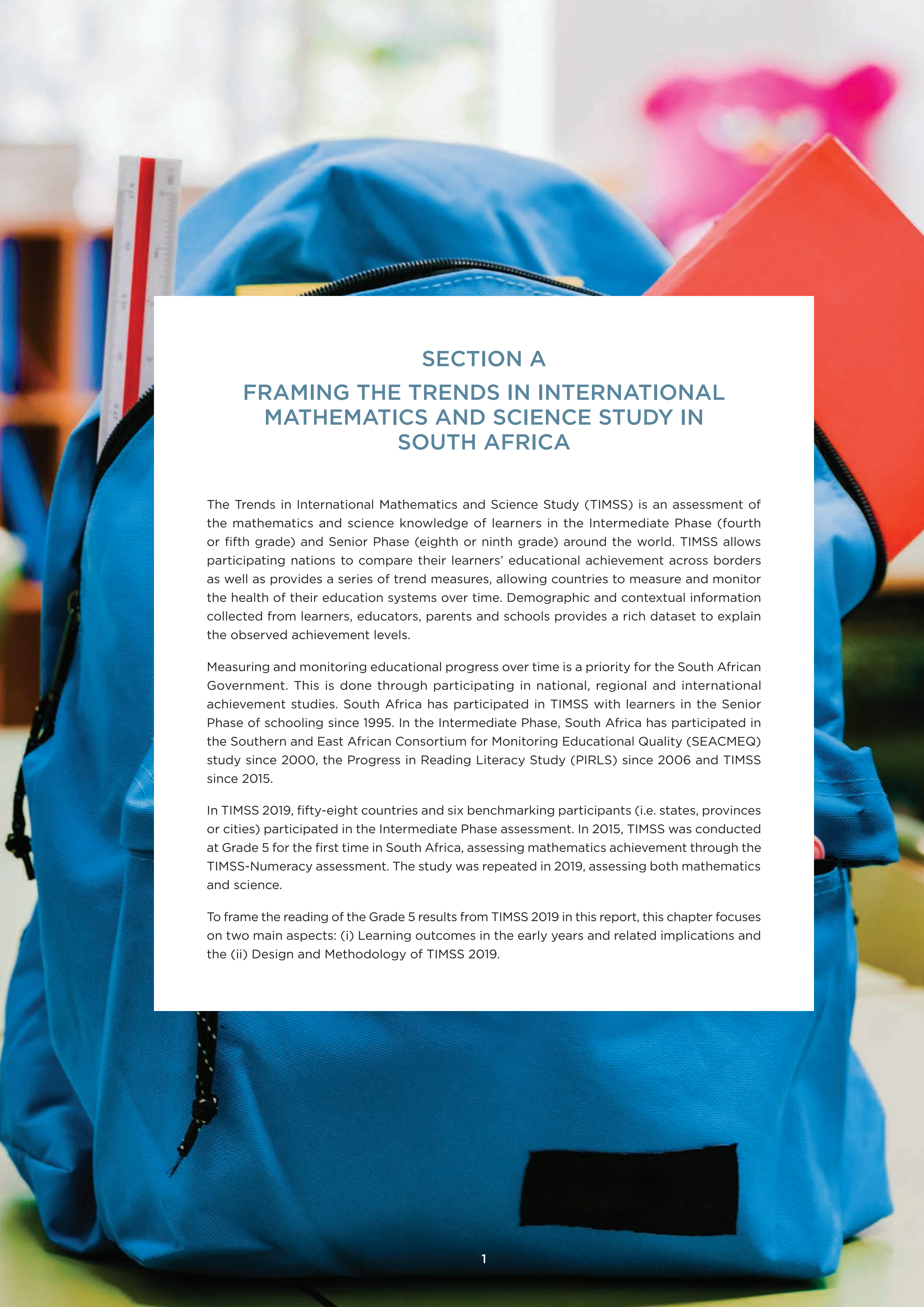
IN CONCLUSION

The South African education system remains a fragile one, and the coronavirus pandemic has dealt it a major blow, especially for the poor and most vulnerable groups. It is predicted that the country will not reach the achievement targets in the Intermediate Phase as set out in the MTSF.

TIMSS 2019 has provided an evaluation of the current South African education system, indicating that our learners are still experiencing multiple barriers to achievement. Building back better and building up the education system, within the context of limited financial and other resources, requires the state to make careful choices.

From the evidence, prioritising the first 1 000 days of a child's formal schooling by building strong educational foundations is an important leverage point to improve the educational performance of learners. This is especially so for learners in no-fee schools whose learning losses have been exacerbated as a result of the coronavirus pandemic. Within the context of school closures and disruptions and reduced and streamlined curricula over the last two years, our recommendation is to focus on building learners' reading, writing and computational skills in the earlier years. This would provide a solid foundation on which subsequent learning will depend.

As is the case with nearly all research investigating the influences on learner achievement, there is no single 'silver bullet' that will fix low performance and remediate years of unequal and socially graded performance throughout the system, but these results highlight that there are many areas that can and must be improved upon.



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 learners in the Intermediate Phase (fourth or fifth grade) and Senior Phase (eighth or ninth grade) around the world. TIMSS allows participating nations to compare their learners' educational achievement across borders as well as provides 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.

Measuring and monitoring educational progress over time is a priority for the South African Government. This is done through participating in national, regional and international achievement studies. South Africa has participated in TIMSS with learners in the Senior Phase of schooling since 1995. In the Intermediate Phase, South Africa has participated in the Southern and East African Consortium for Monitoring Educational Quality (SEACMEQ) study since 2000, the Progress in Reading Literacy Study (PIRLS) since 2006 and TIMSS since 2015.

In TIMSS 2019, fifty-eight countries and six benchmarking participants (i.e. states, provinces or cities) participated in the Intermediate Phase assessment. In 2015, TIMSS was conducted at Grade 5 for the first time in South Africa, assessing mathematics achievement through the TIMSS-Numeracy assessment. The study was repeated in 2019, assessing both mathematics and science.

To frame the reading of the Grade 5 results from TIMSS 2019 in this report, this chapter focuses on two main aspects: (i) Learning outcomes in the early years and related implications and the (ii) Design and Methodology of TIMSS 2019.

CHAPTER ONE

FRAMING THE GRADE 5 TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY IN SOUTH AFRICA

The National Development Plan 2030 (NDP) envisions a South Africa where opportunity is determined not by birth, but rather by ability, **education** and hard work (Republic of South Africa (RSA), 2012: 24). The NDP further emphasises the importance of a strong educational system spanning **early childhood development**, primary, secondary, tertiary and further education. The South African education policy landscape increasingly places Early Childhood Development (ECD) and learning in the early years of schooling at the centre of priorities and strategies that aim to improve the quality of education.

Performance in school mathematics is one of the key indicators to describe and measure the health of our educational system. Numerical, mathematical and analytical skills are key for participation as citizens in a modern society and as workers in the knowledge economy. Learners with sound mathematical skills can participate in higher level cognitive reasoning and problem-solving tasks and possess abilities that make them more easily trainable in a number of jobs, thus giving them higher levels of freedom (Reddy, Juan, Isdale & Fongwa, 2019). Yet, mathematics (and science) under-performance continues to contribute to social inequalities in terms of access and income.

South Africa first participated in the TIMSS 2015 Numeracy assessment for Grade 5 learners and the results from the study provided the country with baseline information regarding our learners' mathematics achievement. This established a new indicator of the health of our education system, especially in the Intermediate Phase (Isdale, Reddy, Juan & Arends, 2017). The key findings regarding mathematics achievement in TIMSS 2015 were that South Africa was one of the lower performers of the set of participating countries; three in five Grade 5 South African learners had not acquired basic mathematical knowledge and skills for the grade; and achievement gaps were evident by school fee-status, province and gender. In short, the results retold the predictable South African story of advantage begetting advantage at one end of the distribution and compounding disadvantage at the other end.

The key recommendations emerging from the TIMSS 2015 Grade 5 results were: (i) Early educational contexts should not just be 'a place to go to', but they should be cognitively rich and stimulating for all children, particularly those who are more likely to come from disadvantaged and poorly resourced households; (ii) Schools should not exacerbate the inequalities that begin at home, compounding early disadvantage through a lack of school resources and poor school climate; (iii) To have the best possible start, Grade 1 learners should spend the first two weeks of school completing the School Readiness Baseline Assessment to identify where learners start; (iv) Ensuring that all learners have individual access to mathematics workbooks is a quick resource win; and (v) The National School Safety Framework designed to support safe and violence-free environments must be implemented to curb the high levels of safety and discipline problems and bullying behaviours in schools.

This Grade 5 TIMSS 2019 report provides an opportunity to measure changes in mathematics achievement from TIMSS 2015, set a baseline measure for Grade 5 science achievement, and identify the contextual factors that are associated with learner achievement.

1.1. EARLY LEARNING: SOLID FOUNDATIONS AND STRONG ROOTS

There is wide recognition that good health and learning experiences for young children will lead to improved personal, educational and social outcomes. The Education for All Global Monitoring Report (2007), titled Strong Foundations: Early Childhood Care and Education (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2006), contended that quality early education experiences, coupled with good health, nutrition and a nurturing environment, can help to ensure a "smooth transition to primary school, a better chance of completing basic education, and a route out of poverty and disadvantage" (UNESCO, 2006: 11). The United Nations Children's Fund (UNICEF, 2017) has strongly advocated that the first 1 000 days of a child's life is the "critical window to ensure that children survive and thrive". They advocate for good nutrition, immunisations and sanitation as the drivers for a healthy start to life.

In addition to the literature promoting investment in children's early health and nutrition, there is also a wide and compelling body of research that shows that cognitive development and learning starts in the early years of an individual's life and is a predictor of later educational, social and economic outcomes (Shonkoff & Phillips, 2000; Cunha & Heckman, 2007). Secondly, gaps in cognitive ability emerge during early childhood due to differences in family background and, over time, these gaps widen (Feinstein, 2003). Thirdly, children with better educated and wealthier parents who perform poorly in early tests tend to catch up, whereas children with less educated and lower income parents are unlikely to catch up (Feinstein, 2003; Blanden & Machin, 2007).

Early childhood education and learning is an integral part of basic education as skills and concepts formed during this phase are necessary for the attainment of future knowledge and skills. South African analysis by Reddy, Van der Berg, Janse van Rensburg and Taylor (2012) showed that there was a strong relationship between Grade 8 and Grade 12 mathematics scores.

> "The strong relationship between Grade 8 and Grade 12 mathematics scores corroborates findings in the literature that earlier mathematics performance and strong foundational knowledge form the foundation for subsequent learning. Analytical skills in mathematics need to be introduced in the early years, and thereafter built on. Mathematical knowledge is hierarchical in nature, and strong prior knowledge is therefore critical for conceptual development. The acquisition of these capabilities is shaped in the early years by the nature and quality of interactions in the home and community, and by the quality of inputs from the school" (Reddy et al., 2012: 7).

The policy implication from these findings is that in order to raise the mathematics scores in Grade 12, scores must be increased in Grade 8. Extrapolating from this, and linking to the literature on cognitive development, we need to raise the mathematics and numeracy scores in the earlier years of schooling. Learners must be familiar with and understand basic concepts; only when they do can they successfully progress. Reddy et al. (2012) showed that, by the time learners reach the secondary school level, it is too late to significantly improve matriculation mathematics performance. Furthermore, increased attention on the early years of learning (Reception year and Foundation Phase) for children from environments with lower household and parental resources would contribute to breaking the cycle of poor academic performance. Without this, both the home and school context will continue to 'let down' South African children and the reproduction of inequality will continue.

Education priorities in South Africa

The South African Government, through the NDP (RSA, 2012b) sets out the plans and targets for development up to 2030. The NDP acknowledges that a strong educational system spanning early childhood development, primary, secondary, tertiary and further education is crucial for addressing poverty and inequality. In particular, the NDP recognises the importance of foundational skills in areas such as mathematics, science, language, the arts and ethics for a good education system (RSA, 2012b: 261). In line with the global focus on the importance of the first 1 000 days of a child's healthy life, the NDP also recognises the importance of zero to five years, and highlights that children need to be nurtured in the home so that they grow up to be healthy, well nourished, physically fit, and cared for in a stable home where they can learn to interact and communicate with those around them (RSA, 2012b: 264).

The predominant long-term education developmental priority stated in the NDP is to increase the percentage of learners reaching adequate achievement levels with respect to their language and mathematical (or numeracy) competencies. The NDP recommends that monitoring of learner outcomes should occur via national assessment programmes, as well as participation in international programmes. The NDP sets out the following educational outcome targets in regional and international studies: (i) to improve Grade 6 mathematics performance in the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SEACMEQ) study from 495 points in 2000 to 600 points in 2022 and (ii) to improve Grade 8 TIMSS scores from 264 points in 2003 to 420 points in 2023 (RSA, 2012b).

A commitment to investment in early childhood development and early learning is also evident in the annual State of the Nation Address (SONA) by the President which outlines government's priorities for each year. In the 2010 SONA, the need to "improve the ability of our children to read, write and count in the foundation years" was highlighted; SONA 2012 reported that Grade R enrolment doubled from 300 000 in 2003 to 705 000 in 2011; and SONA 2018 reiterated that "to break the cycle of poverty, we need to educate the children of the poor". SONA 2019 included the commitment that ECD centres will migrate from the Department of Social Development to the Department of Basic Education (DBE) and "proceed with the process towards two years of compulsory ECD for all children before they enter Grade 1". SONA 2020 again emphasised that "the investments we make now in ECD and early school learning will yield great economic benefits for the next two decades – and beyond". SONA 2021 highlighted the need to give attention to issues affecting children, including improving school-readiness, ECD planning and funding, protection against preventable diseases, policy reform around child welfare and reducing violence against children.

The NDP informed government's Medium-Term Strategic Framework (MTSF) for the 2019–2024 period (Department of Performance Monitoring and Evaluation, 2020). The fundamental goal of the MTSF remains focused on better education outcomes with the commitment that "every 10-year-old will be able to read with meaning". The MSTF highlights the role of the ECD sector but recognises that while there is high access to pre-schools (96 percent and 88 percent of learners in Grade 1 had previously attended Grade R and RR respectively), the attendance of Grade R classes for poor children has shown little effect on learning, indicating a problem in the quality, rather than the quantity, of these spaces. This is in line with other countries that have moved from viewing ECD less as a child protection function and more as an early learning function that is led and coordinated by national ministries of education.

The MTSF promises to develop and operationalise a school readiness assessment system for Grade R learners during this period. The MTSF (2019–2024) includes targets for improved learner outcomes: the target for Grade 5 TIMSS mathematics scores is to improve from 376 in 2015 to 426 in 2023 and the target for Grade 4 PIRLS reading literacy is to improve scores from 320 in 2016 to 355 in 2021 (page 80).

The DBE's Action Plan: 2019–2024 (DBE, 2020) is aligned with the MTSF (2019–2024) and articulates 27 goals for education. Goals 1 to 13 specify the outputs the DBE wants to achieve in relation to learning, and Goals 1 to 3 specify the minimum standards that learners must achieve in numeracy/mathematics and language competencies in Grades 3, 6 and 9.

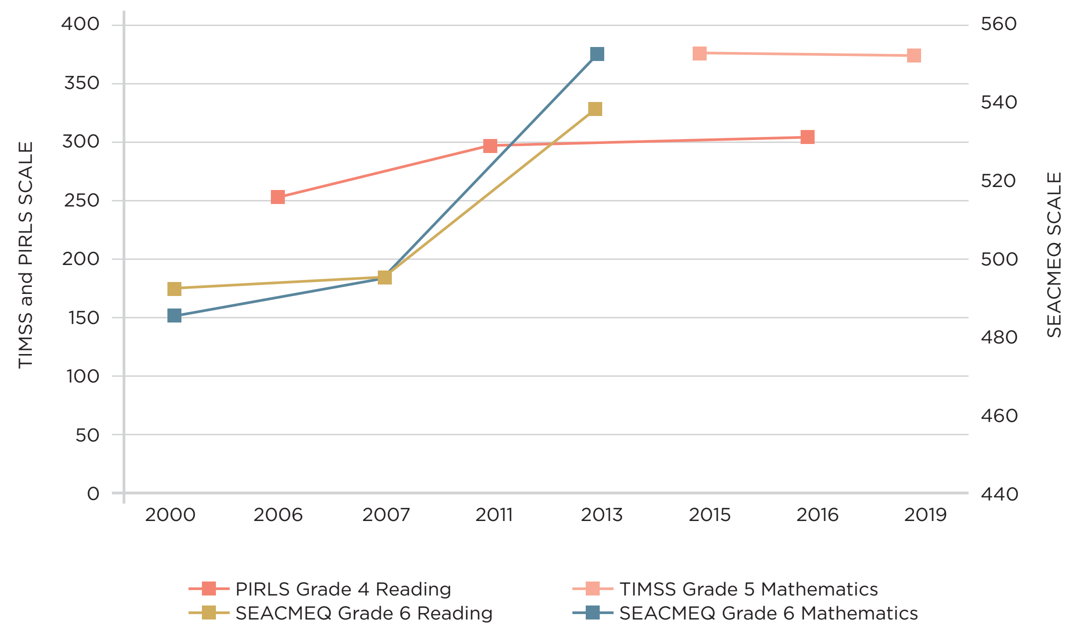
South African educational outcomes in the Intermediate Phase of schooling

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. South Africa participated in PIRLS at the Grade 4 and 5 levels in 2006, 2011, 2016 and 2021 (data were collected in 2021). The SEACMEQ study measures Grade 6 reading literacy and mathematics achievement in about 15 Southern and East African countries. South Africa participated in SACMEQ II (2000), SACMEQ III (2007), SEACMEQ[3] IV (2013) and SEACMEQ V (data were collected in 2021). To obtain additional information about mathematics performance in the Intermediate Phase, South Africa participated in the TIMSS 2015 mathematics assessment at Grade 5. This study was repeated with Grade 5 learners in 2019 and included both the mathematics and science assessments.

To gain a holistic view of educational outcomes for reading and mathematics in the Intermediate Phase, we plotted the average scale scores (refer to Reader's Guide) of all assessments that South Africa learners participated in this phase (Figure 1).

3 In later rounds of the study, SACMEQ changed to SEACMEQ.

Figure 1: South African mathematics and reading scale scores over time in the Intermediate Phase



In general, the PIRLS reading literacy and SEACMEQ mathematics and reading literacy achievement scores improved between the first and latest cycles of South Africa's participation. There are no noticeable achievement changes between the two TIMSS achievement points.

PIRLS and TIMSS are both part of the International Association for the Evaluation of Educational Achievement (IEA) achievement studies and establishing the scale scores and achievement benchmarks for each study uses a similar methodology. The regional SEACMEQ study uses a different methodology to establish its scales scores and achievement benchmarks.

South Africa's reading literacy achievement score was 253 points in PIRLS 2006 (Howie et al., 2007), and this score improved to 302 points in PIRLS 2016 (i.e. an improvement of 50 points over 10 years) (Howie et al., 2017). Translating from scale scores to achievement benchmarks (refer to Reader's Guide), 13 percent of Grade 4 learners scored above the low benchmark of 400 points, thus demonstrating that they could read with meaning in PIRLS 2006. Ten years on, in PIRLS 2016, 22 percent of learners could read with meaning.

South Africa's mathematics achievement did not significantly change between TIMSS 2015 and TIMSS 2019 (with scale scores of 376 and 374 respectively). In 2015, 39 percent of learners had acquired basic mathematical knowledge for that grade. This decreased slightly to 37 percent in 2019.

In SEACMEQ, between 2000 to 2013, the reading literacy scores improved from 492 to 538 (i.e. by 46 points) and the mathematics scores improved from 486 to 552 (i.e. by 66 points). In 2007, 52 percent of learners demonstrated that they could read with meaning. This increased to 75 percent of learners in 2013. For mathematics, the Level 4 benchmark description is that learners demonstrate 'beginning numeracy skills', and the percentage of learners reaching this benchmark increased from 31 percent in 2007 to 50 percent in 2013 (DBE, 2017).

It is in this context and with these policy challenges in mind that South Africa participates in TIMSS. In the next section, we discuss the TIMSS design and methodology and provide details of how we implemented the 2019 Grade 5 study in South Africa.

1.2. TIMSS DESIGN AND METHODOLOGY

What is the Trends in International Mathematics and Science Study (TIMSS)?

TIMSS was developed by the 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: Grade 4 or 5 (South African Intermediate Phase) and Grade 8 or 9 (South African Senior Phase), as well as allowing for comparison across countries.

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

TIMSS 2019 was the seventh cycle of the IEA's series of large-scale assessments of learner achievement dedicated to improving teaching and learning in mathematics and science. The cycles have been conducted every four years since 1995. To inform educational policy in the participating countries, TIMSS also collects extensive background information about the home and school contexts in which teaching and learning take place. This background information is collected through a series of questionnaires that are completed by learners, parents (for Intermediate Phase learners), mathematics and science educators, school principals and curriculum specialists.

Fifty-eight countries, including South Africa, and six benchmarking entities, participated in TIMSS 2019 for Intermediate Phase learners. In addition to the IEA and the TIMSS and PIRLS International Study Center, several other agencies are involved in different aspects of the study. TIMSS sampling procedures were overseen by Statistics Canada and 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 the oversight of the data collection, data processing and data analysis.

In this section we provide an overview of the TIMSS Study Design and Methodology. We provide the operational details and procedures for TIMSS 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 (see South African TIMSS 2019 Grade 9 Results for details). For better insights into achievement in primary schools, in 2015 South Africa participated in the TIMSS-Numeracy assessment at the fifth grade. This less difficult TIMSS mathematics assessment offered an opportunity for learners in lower achieving countries to successfully respond to a greater number of items.

The TIMSS 2019 Grade 5 assessment included both the mathematics and science subject areas. South Africa was one of eleven countries that administered the 'less difficult mathematics' assessment. The other countries were Albania, Bosnia and Herzegovina, Kosovo, Kuwait, Montenegro, Morocco, North Macedonia, Pakistan, the Philippines and Saudi Arabia. This version included some items that were less difficult, while the remainder of the items were the same as in the regular version. An essential aspect of the less difficult mathematics assessment is that the learner achievement results are reported on the same TIMSS achievement scale as the regular mathematics assessment, so that results are comparable regardless of the version of the assessment the learners have taken. There was a single assessment instrument for science.

The TIMSS 2019 Grade 5 assessment provided the second point to monitor and explain South African mathematics achievement in the Intermediate Phase. The key questions informing the analysis of the Grade 5 TIMSS 2019 data in this report are:

- What were the mathematics and science achievements, and achievement gaps, in TIMSS 2019?
- What were the mathematics achievement trends from 2015 to 2019?
- What factors are related to mathematics and science achievement in South Africa?

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

TIMSS conceptual framework

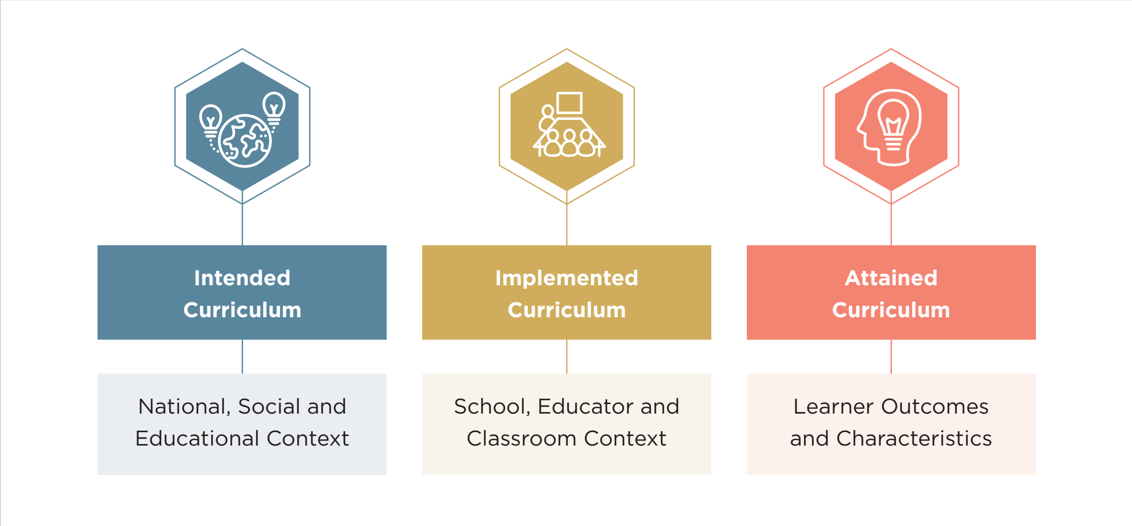
TIMSS uses the curriculum as the key organising concept to evaluate how education opportunities are provided to learners, and to identify the factors that influence how learners use these opportunities. There are three key aspects to the TIMSS Curriculum Model: the intended curriculum, the implemented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

Figure 2: TIMSS Curriculum Model



The TIMSS Assessment Framework

The TIMSS 2019 Assessment Framework[5] (Mullis & Martin, 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 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 Grade 5 participants do in TIMSS 2019?

Learners who participated in TIMSS 2019 at Grade 5 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, each 36 minutes in length, separated by a short break. In addition to completing the achievement booklet, each learner completed a background questionnaire. Learners also took home a questionnaire for their parents or guardians to complete regarding early learning and educational experiences in the home. South African Grade 5 learners sat for the assessment in October and November 2018.

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

The achievement booklets

TIMSS aims to provide 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. For Grade 5, there were seven trend blocks from TIMSS Numeracy 2015, four trend blocks from the regular mathematics, and three new, less difficult blocks were added to make a total of 14 blocks. 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 are included in various cycles and form an anchor that allows for estimating achievement over time. The non-trend items are new items generated for each cycle and are subjected to extensive validation processes. For more details on the assessment frameworks and matrix design refer to the TIMSS 2019 Assessment Frameworks.

The contextual questionnaires

To obtain greater insight into the context within which learning and teaching take place, and identify possible explanations for achievement scores, TIMSS includes a set of contextual questionnaires. These contextual, or background, questionnaires are nationally adapted by each participating country. Adaptations include 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. Five questionnaires were administered in addition to the assessment instruments at Grade 5:

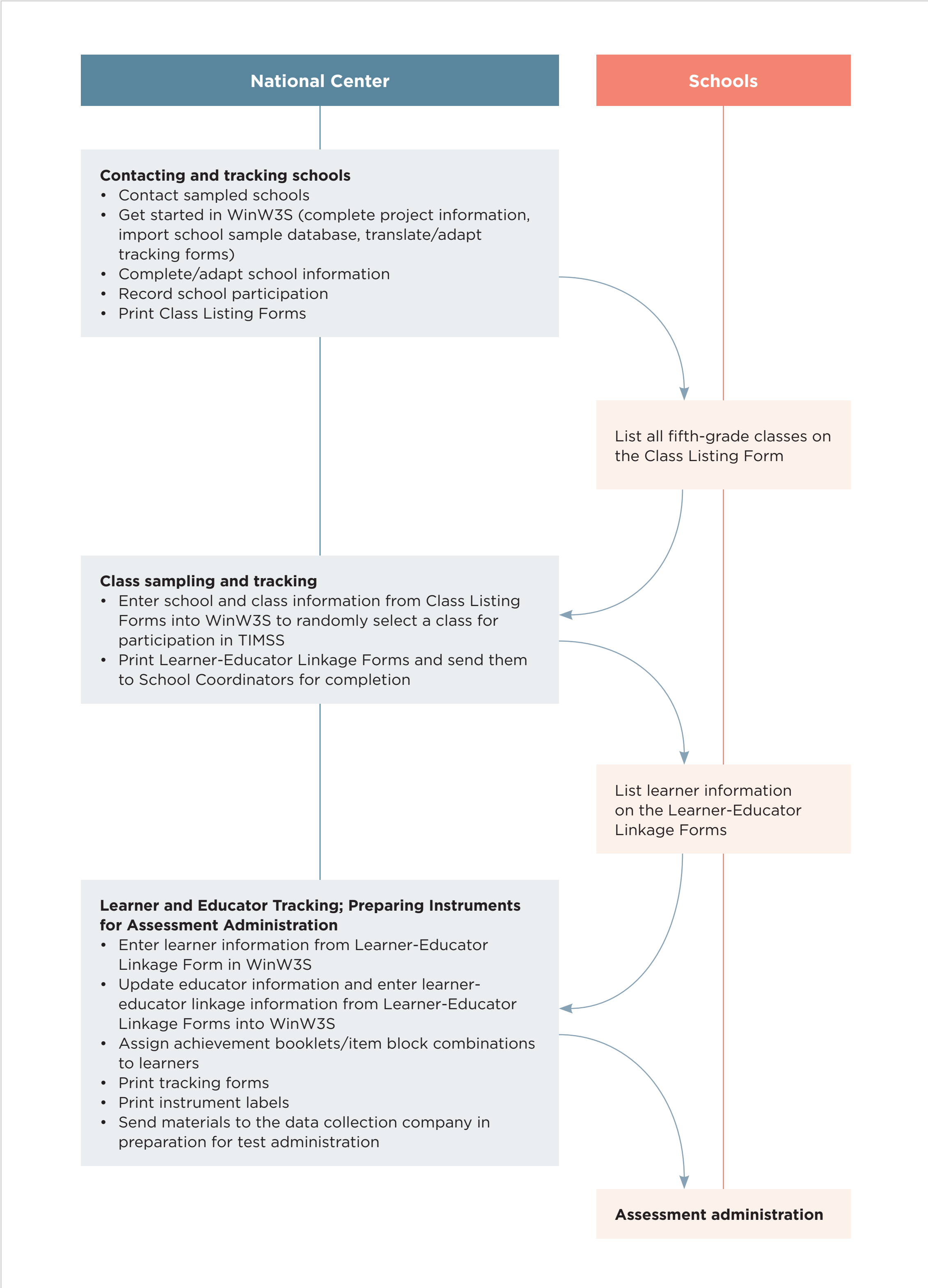
- The **Learner Questionnaire** asks about aspects of the learners' home and school lives, including their home environment, their school climate for learning, and their perceptions and attitudes towards mathematics and science.
- The **Educator Questionnaire** is completed by both the mathematics and 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 the school climate, as well as the extent of parental involvement.
- The **Home Questionnaire** (Early Learning Survey) is completed by the parent or guardian of the learner who completed the assessment and asks about the learner's home context for learning related to aspects such as pre-grade 1 educational activities, learners' school readiness, school involvement, ability of parents to assist learners with homework, and perceptions of school safety.
- 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[6].

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[7]. Figure 3 provides a map of the sampling procedures and logistical preparation to administer TIMSS in classrooms (further details are provided in Annexure 1).

6 https://timssandpirls.bc.edu/timss2019/encyclopedia/
7 https://timssandpirls.bc.edu/timss2019/methods/index.html

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



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

Selecting schools and learners

TIMSS in South Africa drew a representative sample of schools offering Grade 5 classes. TIMSS 2019 followed the sampling procedures described in the TIMSS 2019 Methods and Procedures Manual[8]. In the two-stage stratified cluster sampling design, schools were randomly selected at the first stage and an intact Grade 5 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. In South Africa, we wanted to report achievement estimates by provinces, hence the Grade 5 sample included at least 30 schools from each of the nine 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 (the 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 5 classes and had no missing information on the stratification variables. From this sampling frame, a representative sample of around 30 schools was drawn for each of the nine provinces. In addition to the sample of participating schools, a first and second replacement school were selected, should a school have refused to participate.

Second stage: Schools selected in the first stage submitted a list of all Grade 5 classes in the school. From each of these, an intact class was randomly selected the 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, 300 schools were selected as the TIMSS 2019 Grade 5 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.

The final Grade 5 TIMSS 2019 realised sample included 297 schools with data from 291 principals, 294 mathematics teachers, 295 science teachers, 11 891 learners, and 10 720 parents or caregivers.

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

Provinces	Sampled schools	Participating schools (N)	Participating learners (N)	Proportion of the learner population
Eastern Cape	34	32	1 081	13
Free State	31	31	1 361	6
Gauteng	43	43	1 625	19
KwaZulu-Natal	33	32	1 305	23
Limpopo	33	33	1 434	12
Mpumalanga	31	31	1 519	8
Northern Cape	30	30	1 011	2
North West	31	31	1 376	7
Western Cape	34	34	1 179	10
South Africa	**300**	**297**	**11 891**	**100**

8 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, 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 groups and 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 (the statistical accuracy of the estimate) were rounded to one decimal place.

We report on TIMSS 2019 Grade 5 national achievement in mathematics and science, and achievement trends in mathematics from 2015 to 2019.

Structure of the report

A preliminary report on the 2019 assessment – titled *TIMSS 2019: Highlights of South African Grade 5 Results in Mathematics and Science* – was released in December 2020. The present report expands on the results presented in that Highlights Report.

Chapter 1 has framed the Trends in International Mathematics and Science Study in South Africa. We outlined key theoretical and policy elements focusing on early learning and the TIMSS Design and Methodology.

Chapters 2 and 3 reproduce, with additional detail, the results presented in *TIMSS 2019: Highlights of South African Grade 5 Results in Mathematics and Science*. These chapters describe Grade 5 South African achievement for mathematics and science.

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

Chapters 5 and 6 present the results from the contextual questionnaires and report on learner characteristics and attitudes towards mathematics and science, as well as their home environment and early learning activities.

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

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 the Intermediate Phase in South Africa from TIMSS 2019.

SECTION B
ACHIEVEMENT AND ACHIEVEMENT GAPS

Sixty-four jurisdictions (including 58 countries and six regional entities, called benchmarking participants) participated in the Grade 4 or 5 TIMSS 2019 assessments. Two countries from the African continent participated—Morocco and South Africa—with South Africa being the only country from the sub-Saharan African region. Most countries participated at the fourth grade, whereas Norway, Turkey and South Africa participated at the fifth grade. More than half of the participating countries administered the new computerised version of TIMSS (e-TIMSS), and the remainder administered the traditional paper version. As in the previous cycles, the paper version was administered in South Africa.

TIMSS describes performance in two ways: The first is through the achievement scale score, while the second is by characterising learners as having reached one of a set of defined 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 results for each of the participating countries, including South Africa. We then discuss South African Grade 5 learners' performance in relation to the international achievement benchmarks. In Chapter 2, we end the discussion by presenting the trend in mathematics achievement from the 2015 to 2019 cycles.

The second part of each chapter is informed by HSRC analyses in describing scale scores by locally relevant variables *viz*. province and the socioeconomic status of schools.

CHAPTER TWO

MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

Learning mathematics and developing numeracy skills start in the earlier years and introduce children to concepts, skills and strategies that are essential in everyday life and that support learning across the curriculum. Mathematics helps children make sense of the numbers, patterns and shapes they see in the world around them, offers ways of effectively handling data in an increasingly digital world, and makes a crucial contribution to their development as successful learners. Mathematics offers children a powerful way of communicating, interacting and participating in the world. They learn to explore and explain their ideas using symbols, diagrams, and spoken and written language. Studying mathematics stimulates curiosity, fosters creativity and equips children with the skills they need in life beyond school. The mathematical knowledge and skills acquired in the earlier years predicts later mathematics achievement.

2.1. MATHEMATICS ACHIEVEMENT

Mathematics achievement in an international context

Figure 4 presents, in rank order, the mathematics average scale scores, together with the standard errors (see Reader's Guide), of the 58 countries that participated in the Intermediate Phase of primary school (fourth and fifth grade) assessments in 2019, together with the scale score distribution underlying the scale score. 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. Then, we present the scale score range within each country by calculating the achievement difference between the 5th and 95th percentiles.

The countries are arranged from highest to lowest mathematics scale score. The five top performing countries were Singapore (with an average scale score of 625), Hong Kong (602), the Republic of Korea (600), Chinese Taipei (599) and Japan (593) – all from East Asia. The five countries with the lowest achievement were Morocco (383), Kuwait (383), South Africa (374), Pakistan (328) and the Philippines (297). The South African achievement score was significantly higher than that of Pakistan and the Philippines but was not significantly different from Morocco or Kuwait's achievement scores.

A total of 37 countries obtained scores higher than the TIMSS centrepoint of 500. The achievement distribution inequality (refer to Reader's Guide) within countries, defined as the score difference between the 5th and 95th percentile, ranged from 198 points for the Netherlands to 368 points for Kuwait. The achievement distribution inequality was less than 300 points in 46 countries; and 12 countries, including South Africa, had a distribution inequality greater than 300 points. Countries with the highest distributional inequality were Kuwait, the Philippines and Oman; and those with the lowest distributional inequality were the Netherlands, Austria and Italy.

TIMSS achievement scale score

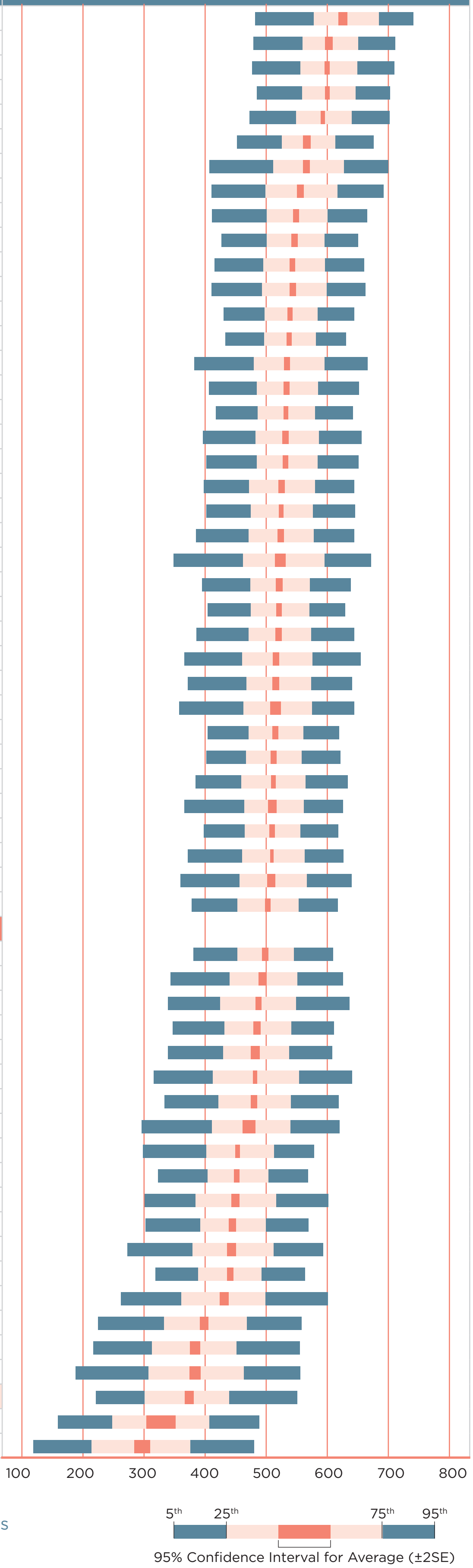
Each learner responds to only a subset of the TIMSS assessment items as the full item bank is too large. TIMSS therefore utilises Item Response Theory (IRT) in combination with population modelling to provide estimated achievement scores as though each learner had answered all items. The IRT or scale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

Figure 4: Average mathematics scale score and distribution, by country

Country	Average Scale Score	(SE)	Score difference between 5th and 95th percentiles
Singapore	625	(3.9)	259
Hong Kong, SAR	602	(3.3)	233
Korea, Rep. of	600	(2.2)	232
Chinese Taipei	599	(1.9)	218
Japan	593	(1.8)	229
Russian Federation	567	(3.3)	225
Northern Ireland	566	(2.7)	294
England	556	(3.0)	282
Ireland	548	(2.5)	254
Latvia	546	(2.6)	223
Norway (5)	543	(2.2)	245
Lithuania	542	(2.8)	249
Austria	539	(2.0)	214
Netherlands	538	(2.2)	198
United States	535	(2.5)	284
Czech Republic	533	(2.5)	246
Belgium	532	(1.9)	224
Cyprus	532	(2.9)	261
Finland	532	(2.3)	250
Portugal	525	(2.6)	246
Denmark	525	(1.9)	243
Hungary	523	(2.6)	260
Turkey (5)	523	(4.4)	324
Sweden	521	(2.8)	244
Germany	521	(2.3)	225
Poland	520	(2.7)	258
Australia	516	(2.8)	289
Azerbajan	515	(2.7)	269
Bulgaria	515	(4.3)	286
Italy	515	(2.4)	215
Kazakhstan	512	(2.5)	220
Canada	512	(1.9)	250
Slovak Republic	510	(3.5)	259
Croatia	509	(2.2)	221
Malta	509	(1.4)	255
Serbia	508	(3.2)	280
Spain	502	(2.1)	239
TIMSS scale centrepoint	500		
Armenia	498	(2.5)	228
Albania	494	(3.4)	283
New Zealand	487	(2.6)	297
France	485	(3.0)	264
Georgia	482	(3.7)	269
United Arab Emirates	481	(1.7)	325
Bahrain	480	(2.6)	285
North Macedonia	472	(5.3)	324
Montenegro	453	(2.0)	280
Bosnia and Herzegovina	452	(2.4)	246
Qatar	449	(3.4)	301
Kosovo	444	(3.0)	266
Iran, Islamic Rep. of	443	(3.9)	320
Chile	441	(2.7)	245
Oman	431	(3.7)	339
Saudi Arabia	398	(3.6)	334
Morocco	383	(4.3)	338
Kuwait	383	(4.7)	368
South Africa (5)	**374**	**(3.6)**	**330**
Pakistan	328	(12.0)	330
Philippines	297	(6.4)	361

Mathematics Achievement Distribution



Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

Reading a distribution or percentile graph

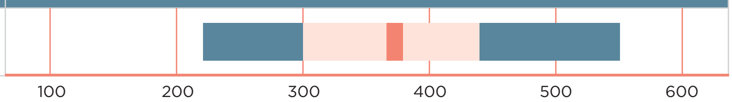
A percentile indicates the value in the distribution of scores below which a percentage of the population can be found. For example, if the 5th percentile of the distribution is 200, this means that five percent of the distribution will be below 200 and 95 percent of the distribution surpasses this value. The TIMSS distribution graphs are drawn from the 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 first blue section of the bar covers the range between the 5th and 25th percentiles. The first light coral section shows the range of scores between the 25th 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 coral section represents the scores between the upper limit of the confidence interval and the 75th percentile, and the blue section shows the scores between the 75th and 95th percentiles.

South African mathematics achievement and learners reaching international achievement benchmarks

Figure 5 presents the average mathematics achievement scale score for South Africa, together with the scale score distribution. The Grade 5 South African average scale score for mathematics was 374 (3.6)[9]. The achievement distributional inequality between the 95th and 5th percentile was 330 points. This wide distribution reflects the high variance between low and high performing learners.

The ideal is to have a narrower distribution (of higher scores) which would mean less variation between learners' mathematics scores, and hence provide an indication that a country's education system is becoming more equitable, and that the quality of education provided to learners is similar irrespective of the schools that they attend. Cross-country studies undertaken by the Organisation for Economic Co-operation and Development (OECD) have found that the highest performing education systems are those that combine quality with equity (OECD, 2012).

Figure 5: Average South African Grade 5 mathematics achievement and scale score distribution

	Average Scale Score (SE)	Achievement Distribution
Mathematics	374 (3.6)	

Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

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

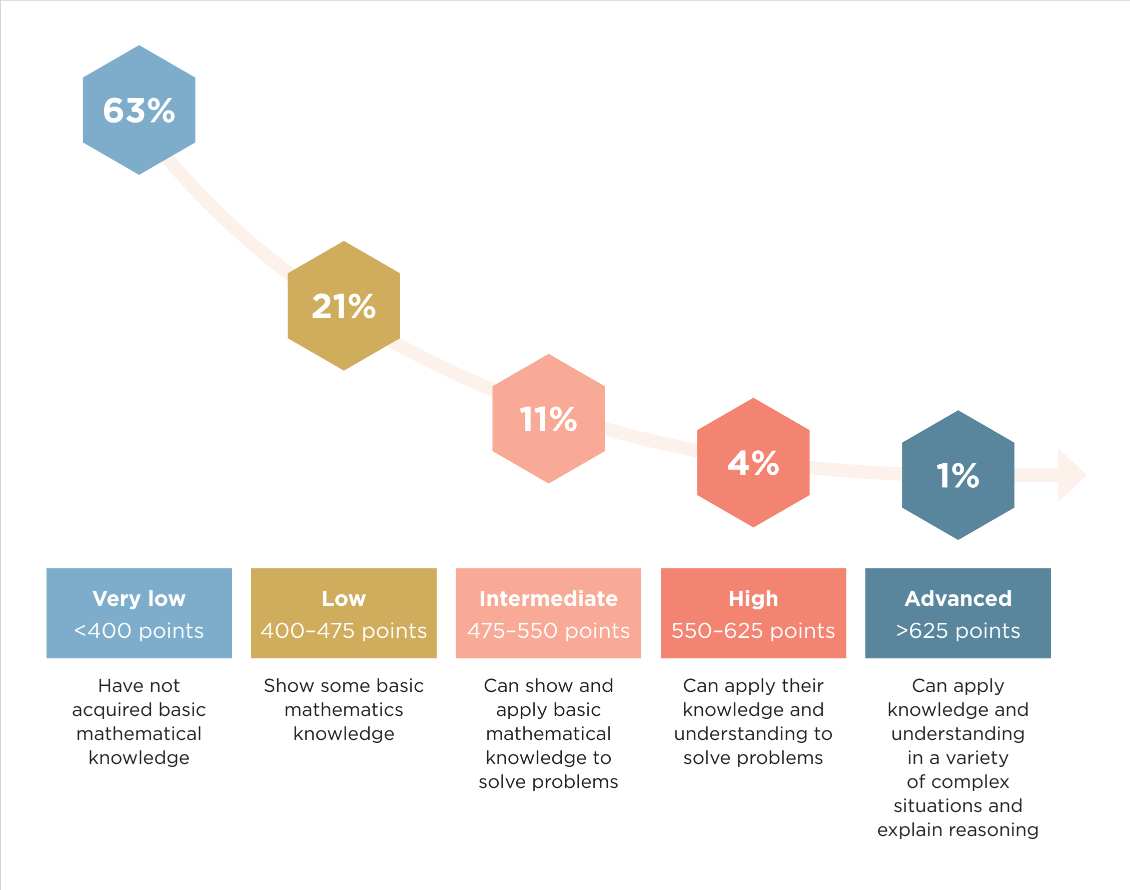
International achievement benchmarks are used to describe the abilities learners demonstrate (i.e. what learners know) at particular points on the achievement scale. TIMSS describes four points on the scale in terms of ability: Low (400 to 475 points); Intermediate (475 to 550 points); High (550 to 625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

9 The **standard error (SE)** gives us an estimate of where the true achievement lies. 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 5 learners in the country were to have written the assessment.

The **confidence interval (CI)** is a range of values that you can be 95% 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 provides the percentage of South African Grade 5 learners who reached each of the international achievement benchmarks for mathematics in 2019. 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.

Figure 6: Percentage of learners reaching mathematics international achievement benchmarks



Source: TIMSS 2019 South African Grade 5 dataset.

Cumulatively, 37 percent of South African Grade 5 learners demonstrated that they had reached the Low International Benchmark and acquired basic mathematical knowledge, achieving 400 points or higher. In contrast, the majority (63%) of learners did not exhibit mastery of basic mathematical knowledge. The country still has a 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.

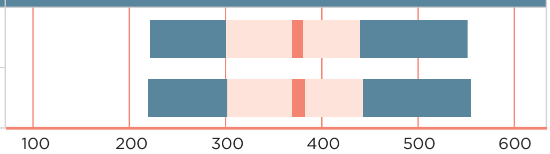
It is, however, noteworthy that one percent of South African mathematics learners achieved at the advanced benchmark, attaining scores higher than 625 points. In subsequent analyses, we combine the *High* and *Advanced* International Benchmarks and use the term 'High International Benchmark' to describe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

Trends in mathematics achievement and achievement benchmarks (TIMSS 2015 to 2019)

TIMSS 2015 and 2019 measured mathematics achievement at Grade 5 in South Africa, thus providing trend data. The average mathematics scale score was 376 (3.5) in 2015 and 374 (3.6) in 2019 (Figure 7). This two-point difference was not statistically significant[10].

Figure 7: Trends in average mathematics scale score and distribution from 2015 to 2019

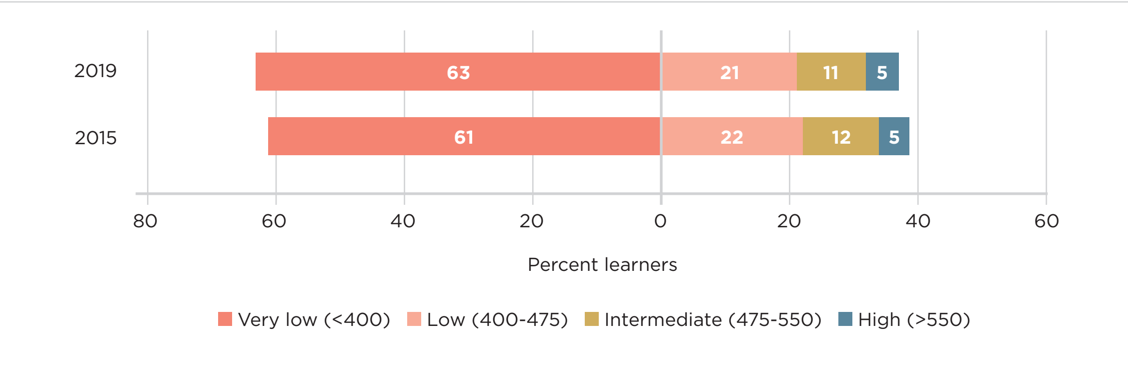
	Average Scale Score (SE)	Score difference between 5th and 95th percentiles	Achievement Distribution
Gr 5 TIMSS 2019	374 (3.6)	330	
Gr 5 TIMSS 2015	376 (3.5)	335	



Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

As would be expected, in line with the consistency in the mathematics achievement between 2015 and 2019, similar patterns were found in the mathematical ability levels of learners in 2015 and 2019 (Figure 8). In 2015, 39 percent of learners demonstrated that they had acquired basic mathematical skills and knowledge. This decreased to 37 percent in 2019, but this difference was not statistically significant.

Figure 8: Trends in percentage of learners reaching international achievement benchmarks from 2015 to 2019



Source: TIMSS 2019 and 2015 South African Grade 5 dataset.

10 **Statistical Significance.** When a finding is statistically significant it means that the difference is unlikely to be due to chance. We used the t-statistic for significance testing and report findings at the 95% confidence level.

2.2. MATHEMATICS 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 the locally relevant categories of (i) the province in which the school is located, and (ii) the socioeconomic status (SES) of the school.

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

The TIMSS 2019 Grade 5 provincial mathematics achievement scores, with standard errors (see Reader's Guide), are shown in Table 2. Comparisons between the provinces are also presented. The mathematics estimates were derived from a sample of around 30 schools per province. This smaller sample – relative to the national one – results in higher standard errors.

The top three performing provinces for mathematics were the Western Cape with an average scale score of 441, Gauteng with 410 and Free State with 387. The scale scores for the six other provinces, Northern Cape, KwaZulu-Natal, Eastern Cape, North West, Mpumalanga, and Limpopo, were lower than the national average score. The average achievement score for the Western Cape was significantly different from all other provinces.

The mathematics average achievement difference between the highest and lowest performing provinces was 110 points, quantifying the provincial mathematics achievement gap.

Table 2: Average provincial mathematics scale score and comparison between provinces

		Comparison province								
Province	Average Mathematics Scale Score	Western Cape	Gauteng	Free State	Northern Cape	KwaZulu-Natal	Eastern Cape	North West	Mpumalanga	Limpopo
Western Cape	441 (9.6)		▲	▲	▲	▲	▲	▲	▲	▲
Gauteng	410 (10.7)	▽			▲	▲	▲	▲	▲	▲
Free State	387 (12.6)	▽					▲	▲	▲	▲
Northern Cape	372 (9.9)	▽	▽						▲	▲
KwaZulu-Natal	360 (6.7)	▽	▽							▲
Eastern Cape	357 (8.2)	▽	▽	▽						▲
North West	355 (7.2)	▽	▽	▽						▲
Mpumalanga	343 (10.3)	▽	▽	▽	▽					
Limpopo	331 (9.4)	▽	▽	▽	▽	▽	▽	▽		

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: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

When comparing the changes in provincial mathematics achievement scores[11] from TIMSS 2015 to 2019, some provincial scores increased, while others decreased or remained the same. Only one provincial achievement change was statistically significant: the achievement scores in Mpumalanga decreased by a statistically significant 40 points.

Mathematics achievement by socioeconomic status of the school

South African schools vary considerably regarding the area in which they are located, and their access to infrastructure and resources. The Department of Basic Education (DBE) calculated a poverty index for each public school according to the income levels of the community around the school, as well as the unemployment rate and 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 3 reports the average mathematics achievement for schools in each quintile category, as well as for independent schools, and provides comparisons between them. The average mathematics achievement for learners in Quintile 1 and 2 schools was similar, with no significant differences being observed. The average mathematics achievement of learners in Quintile 4 schools (390 points) was significantly different from the scores in all other school types. The average mathematics achievement of learners in Quintile 5 schools (487 points) was not statistically different from learners in independent schools (463 points).

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

		Comparison quintile					
Quintile Rank	Average Mathematics Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	463 (14.4)			▲	▲	▲	▲
Quintile 5	487 (7.5)			▲	▲	▲	▲
Quintile 4	390 (7.4)	▽	▽		▲	▲	▲
Quintile 3	354 (6.1)	▽	▽	▽			▲
Quintile 2	337 (6.0)	▽	▽	▽			
Quintile 1	331 (3.4)	▽	▽	▽	▽		

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: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

11 We cautiously compare provinces as the sample size of 30 schools per province leads to high standard errors and confidence intervals.

Mathematics 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 (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 South African Grade 5 learners attend no-fee schools and one-third attend fee-paying schools.

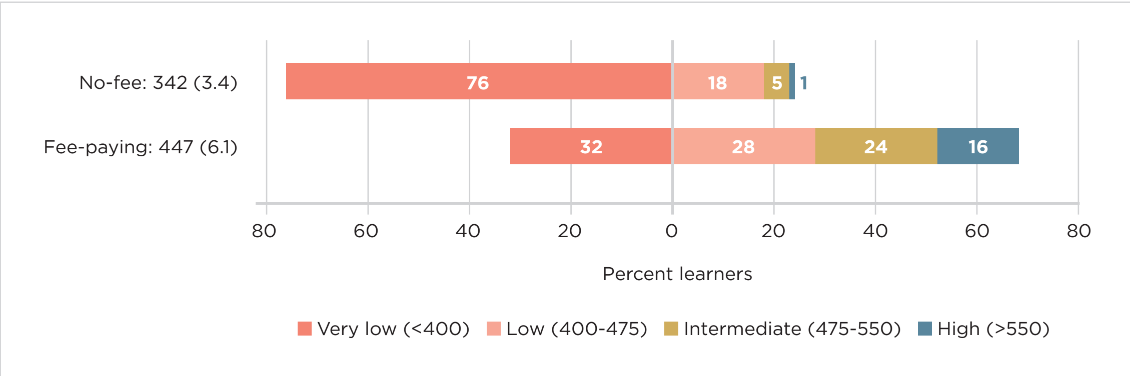
The general description of learners attending no-fee schools is that they come from lower income households, live in poorer communities, attend schools with fewer resources, and are largely taught by educators with less specialist knowledge. Learners in fee-paying schools on the other hand, come from largely higher income households in better resourced communities, and attend schools with better qualified educators and a climate that promotes better teaching and learning.

As expected, the differences in the material school and home conditions for learners attending no-fee and fee-paying schools lead to unequal achievements. In 2019, the average mathematics score for Grade 5 learners in no-fee schools was 342 (3.4) and in fee-paying schools it was 447 (6.1). This means a mathematics achievement gap of just over a standard deviation, 105 points, between learners attending no-fee and fee-paying schools.

Figure 9 describes the percentage of learners reaching the different international achievement benchmarks by school fee-status. The percentage of learners to the right of the '0' point had acquired the basic knowledge and skills for Grade 5 (scoring 400 points or more), while the percentage of learners to the left of the '0' point had not acquired basic mathematical knowledge and skills.

When the achievement scale scores are described in terms of ability levels, two out of three learners (68%) in fee-paying schools reached the Low International Benchmark, thus demonstrating that they acquired basic mathematical knowledge and skills. It is noteworthy that 16 percent of learners in fee-paying schools achieved scores above the High International Benchmark score of 550 points. These learners had the ability to apply their mathematical knowledge to solve problems. By comparison, in no-fee schools, only one in four learners (24%) had acquired basic mathematical knowledge and skills. This means that three-quarters (76%) of learners in no-fee schools had not acquired the basic mathematical knowledge and skills for Grade 5.

Figure 9: Average mathematics scale score and percentage of learners reaching international achievement benchmarks, by school fee-status



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

In the infographic that follows we provide a summary of the mathematics achievement and achievement gaps for Grade 5 learners in TIMSS 2019.

2.3. SUMMARY: MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

Mathematics performance

South Africa was one of the lower performing countries from the set of TIMSS 2019 participating countries. The average Grade 5 mathematics scale score of 374 (3.6) was well below the TIMSS centrepoint of 500 points.

Thirty-seven percent of mathematics learners reached the low benchmark, thus demonstrating that they had acquired basic content knowledge and skills. In contrast, 63 percent of learners did not exhibit mastery of basic mathematical knowledge. It is noteworthy that five percent of Grade 5 South African learners reached the higher international benchmarks, meaning that they were able to apply their knowledge and understanding to solve problems.

Trends in mathematics performance

From TIMSS 2015 to 2019 there was no statistically significant difference in South African mathematics achievement.

Mathematics achievement inequality

The achievement distribution inequality, i.e. the achievement difference between the 5th and 95th percentiles, in the 2019 cycle for mathematics was 330 points. This was one of the higher distributional inequalities in the set of participating countries.

Provincial mathematics achievements

The best performing provinces for mathematics were the Western Cape, Gauteng and the Free State, with the Western Cape scoring significantly higher achievement scores than all other provinces. The lowest performing provinces were Mpumalanga and Limpopo. The provincial mathematics achievement gap between the highest and lowest performing provinces was 110 points.

From 2015 to 2019 the average mathematics scale scores for Mpumalanga decreased by a significant 40 points.

Mathematics performance by socioeconomic status of the school

The average mathematics score for learners in no-fee schools was 342 (3.4) and in fee-paying schools it was 447(6.0), leading to a mathematics achievement gap of 105 points.

Only one in four learners (24%) in no-fee schools, compared to two in three learners (68%) in fee-paying schools, demonstrated that they had acquired basic mathematical knowledge and skills.

The average scale scores of learners in Quintile 5 and independent school were not statistically different. There is a continuity of disadvantage from home to schools. The achievement difference between the learners from affluent and less resourced homes begins early.

The next chapter focuses on Grade 5 learners' TIMSS science achievement and achievement gaps.

CHAPTER THREE

SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Children are naturally curious. Science in primary schools should nurture this curiosity and allow children to ask questions and develop the skills they need to answer those questions. Understanding science therefore helps children to appreciate the world around them by teaching them to make observations, collect information and to use logical thinking to draw conclusions in order to solve life's daily challenges. Science also encourages and enables learners to explore their world and discover new things. It is an active subject, incorporating activities such as hands-on laboratory work and experiments. This makes science well-suited to active younger children.

3.1. SCIENCE ACHIEVEMENT

Science achievement in an international context

Figure 10 presents, in rank order, the average science scale scores, together with the standard errors (SE) of the 58 countries that participated in the Intermediate Phase of primary school (fourth and fifth grade) assessments, together with the distribution underlying the scale score. 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 uses scale score to refer to learner achievement (see Reader's Guide). Then, we present the scale score range within each country by calculating the achievement difference between the 5th and 95th percentiles.

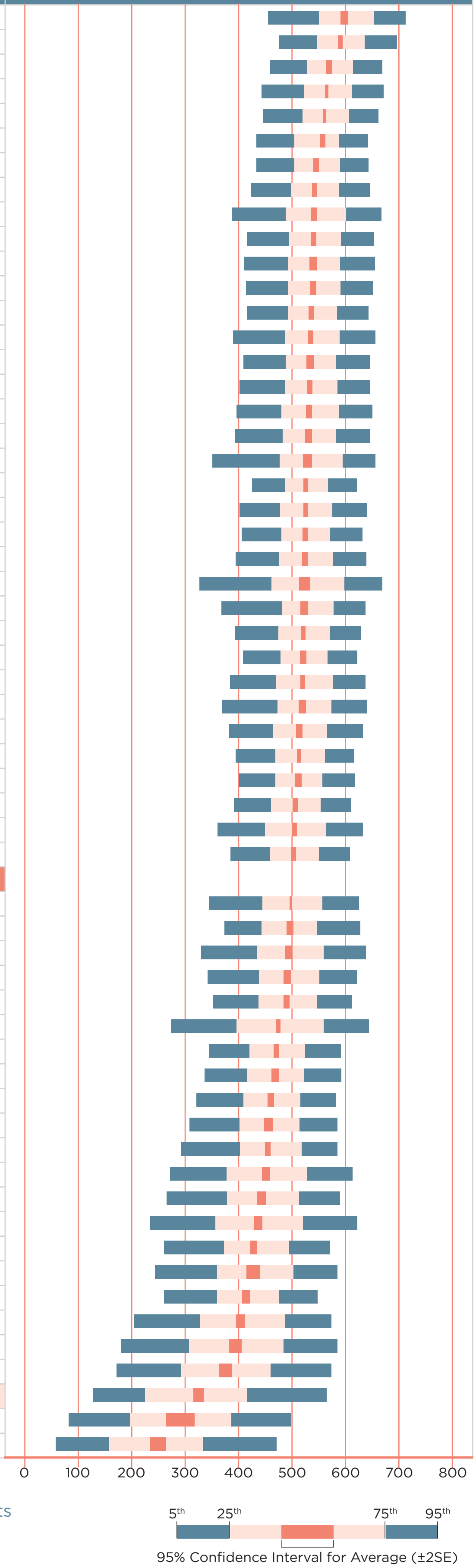
The countries are arranged from highest to lowest science scale score. The top five countries in TIMSS 2019 were Singapore with an average science score of 595, the Republic of Korea (588), the Russian Federation (567), Japan (562) and Chinese Taipei (558). The five lowest achieving countries were the same as for mathematics: Kuwait with an average science score of 392, Morocco (374), South Africa (324), Pakistan (290) and the Philippines (249). The South African science scores were significantly higher than that of both Pakistan and the Philippines, and significantly lower than Kuwait and Morocco.

In general, most countries performed well, with 35 countries scoring above the centrepoint of 500. The score difference between the highest and lowest performing countries was substantial, at 346 TIMSS points. The achievement distribution inequality within countries, defined as the score difference between the 5th and 95th percentile, ranged from 194 points for Croatia to 434 points for South Africa. The achievement distribution inequality was less than 300 points in 35 countries; and 23 countries, including South Africa, had a distribution inequality greater than 300 points. The countries with the highest distributional inequality were the three lowest performing countries: South Africa (434 points), Pakistan (413 points) and the Philippines (411 points).

Figure 10: Average science scale score and distribution, by country

Country	Average Scale Score (SE)		Score difference between 5th and 95th percentiles
Singapore	595	(3.4)	254
Korea, Rep. of	588	(2.1)	219
Russian Federation	567	(3.0)	209
Japan	562	(1.8)	226
Chinese Taipei	558	(1.8)	215
Finland	555	(2.6)	207
Latvia	542	(2.4)	207
Norway (5)	539	(2.2)	221
United States	539	(2.7)	277
Lithuania	538	(2.5)	236
Sweden	537	(3.3)	243
England	537	(2.7)	235
Czech Republic	534	(2.6)	226
Australia	533	(2.4)	264
Hong Kong SAR	531	(3.3)	235
Poland	531	(2.6)	242
Hungary	529	(2.7)	251
Ireland	528	(3.2)	250
Turkey (5)	526	(4.2)	302
Croatia	524	(2.2)	194
Canada	523	(1.9)	236
Denmark	522	(2.4)	224
Austria	522	(2.6)	243
Bulgaria	521	(4.9)	340
Slovak Republic	521	(3.7)	267
Northern Ireland	518	(2.3)	235
Netherlands	518	(2.9)	212
Germany	518	(2.2)	251
Serbia	517	(3.5)	269
Cyprus	511	(3.0)	248
Spain	511	(2.0)	220
Italy	510	(3.0)	215
Portugal	504	(2.6)	217
New Zealand	503	(2.3)	269
Belgium	501	(2.1)	221
TIMSS scale centrepoint	500		
Malta	496	(1.3)	279
Kazakhstan	494	(3.1)	252
Bahrain	493	(3.4)	306
Albania	489	(3.5)	277
France	488	(3.0)	258
United Arab Emirates	473	(2.1)	367
Chile	469	(2.6)	246
Armenia	466	(3.4)	254
Bosnia and Herzegovina	459	(2.9)	259
Georgia	454	(3.9)	275
Montenegro	453	(2.5)	290
Qatar	449	(3.9)	339
Iran, Islamic Rep. of	441	(4.1)	322
Oman	435	(4.1)	385
Azerbajan	427	(3.3)	308
North Macedonia	426	(6.2)	339
Kosovo	413	(3.7)	285
Saudi Arabia	402	(4.1)	366
Kuwait	392	(6.1)	401
Morocco	374	(5.8)	399
South Africa (5)	**324**	**(4.9)**	**434**
Pakistan	290	(13.4)	413
Philippines	249	(7.5)	411

Science Achievement Distribution



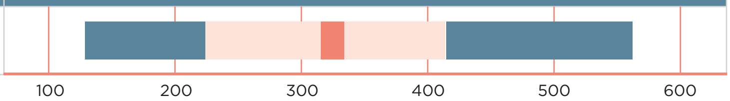
Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

South African science achievement and international achievement benchmarks

TIMSS describes science performance in two ways: scale scores and international achievement benchmarks. Figure 11 presents the average science achievement, at the fifth grade, for South Africa together with the scale score distribution. The average science scale score for South African Grade 5 learners was **324 (SE 4.9)**. A total of 434 points separated the 5th and 95th percentiles, which is the largest inequality distribution (see Reader's Guide) of all participating countries. Furthermore, the science achievement distribution inequality of scores was higher than the mathematics inequality distribution of 330 points.

Figure 11: Average South African Grade 5 science achievement and scale score distribution

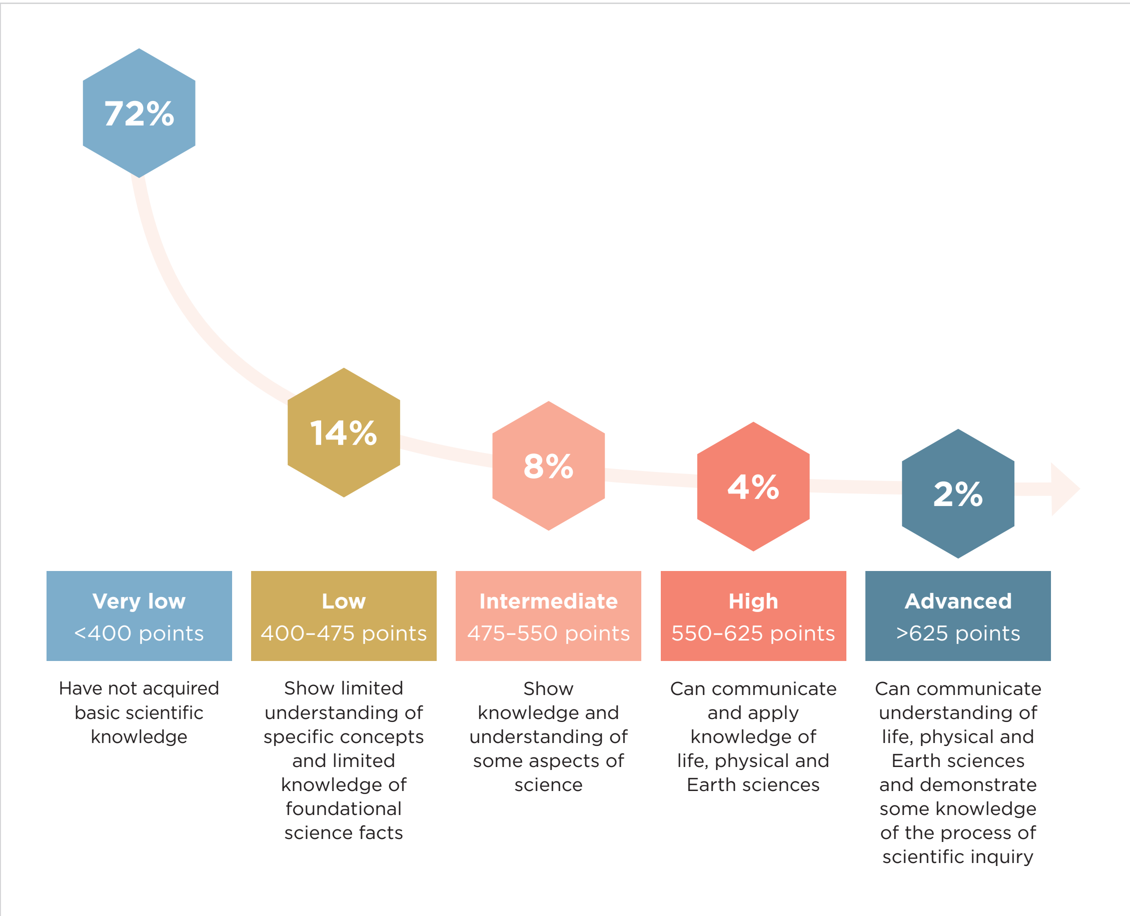
	Average Scale Score (SE)	Achievement Distribution
Science	324 (4.9)	



Source: TIMSS 2019 South African Grade 5 dataset.

Further insight into learner achievement is derived from describing their performance in relation to the international achievement benchmarks. Figure 12 provides the percentage of South African Grade 5 learners who reached each of the defined benchmarks for science. 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 12: Percentage of learners reaching science international achievement benchmarks



Source: TIMSS 2019 South African Grade 5 dataset.

Cumulatively, 28 percent of South African Grade 5 learners reached the Low International Benchmark, thus demonstrating that they had acquired basic scientific knowledge, achieving 400 points or higher. The remaining 72 percent of learners did not exhibit mastery of basic scientific knowledge. The country still has a very long way to go to improve science achievement: in addition to being a very low performing country, South Africa had science scores well below the TIMSS Grade 5 mathematics scores. It is, however, noteworthy that two 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.

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 nuanced achievement story reported by locally relevant categories of (i) the province in which the school is located, and (ii) the socioeconomic status of the school.

Science achievement by province

The nine provincial departments of education are responsible for funding decisions and for implementing education policy and programmes in Grades R to 12. Provincial achievement estimates provide information to monitor the progress across the nine education departments.

The TIMSS 2019 Grade 5 provincial science achievement scores, with standard errors, are presented in Table 4. Comparisons between the provinces are also presented.

The science achievement estimates were derived from a sample of around 30 schools per province. This smaller sample – relative to the national one – results in higher standard errors. For science, the three top performing provinces were again Western Cape with an average scale score of 415 points, Gauteng with a score of 379 points and Free State with 333 points; and the three lowest performing provinces were Eastern Cape with 297 points, Mpumalanga with 284 points and Limpopo with 274 points.

The Western Cape and Gauteng had significantly different average science achievement scores to all other provinces at the 95 percent confidence level. The average achievement between these two provinces was significantly different at the 90 percent confidence level.

The average science achievement difference between the highest and lowest performing provinces was 141 points, quantifying the science achievement gap.

Table 4: Average provincial science scale score and comparison between provinces

		Comparison province								
Province	Average Science Scale Score	Western Cape	Gauteng	Free State	Northern Cape	KwaZulu-Natal	North West	Eastern Cape	Mpumalanga	Limpopo
Western Cape	415 (12.1)			▲	▲	▲	▲	▲	▲	▲
Gauteng	379 (15.6)			▲	▲	▲	▲	▲	▲	▲
Free State	333 (17.4)	▽	▽						▲	▲
Northern Cape	330 (13.2)	▽	▽					▲	▲	▲
KwaZulu-Natal	302 (9.2)	▽	▽							
North West	299 (10.7)	▽	▽							
Eastern Cape	297 (10.8)	▽	▽		▽					
Mpumalanga	284 (14.2)	▽	▽	▽	▽					
Limpopo	274 (11.5)	▽	▽	▽	▽					

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: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

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. 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 the best resourced schools.

Table 5 reports the average science achievements for schools in each quintile category, as well as for independent schools, and provides the comparisons between them. The science average achievement scores for learners in Quintile 1 and 2 schools was not statistically different. The average mathematics score for learners in Quintile 4 schools was significantly higher than learners in Quintile 3 schools and significantly lower than learners in Quintile 5 schools. The average achievement between learners in Quintile 5 and independent schools was not significantly different.

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

		Comparison quintile					
Quintile Rank	Average Science Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	448 (19.1)			▲	▲	▲	▲
Quintile 5	483 (10.2)			▲	▲	▲	▲
Quintile 4	352 (10.0)	▽	▽		▲	▲	▲
Quintile 3	299 (8.1)	▽	▽	▽		▲	▲
Quintile 2	270 (8.0)	▽	▽	▽	▽		
Quintile 1	263 (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: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Science achievement and ability levels by school fee-status

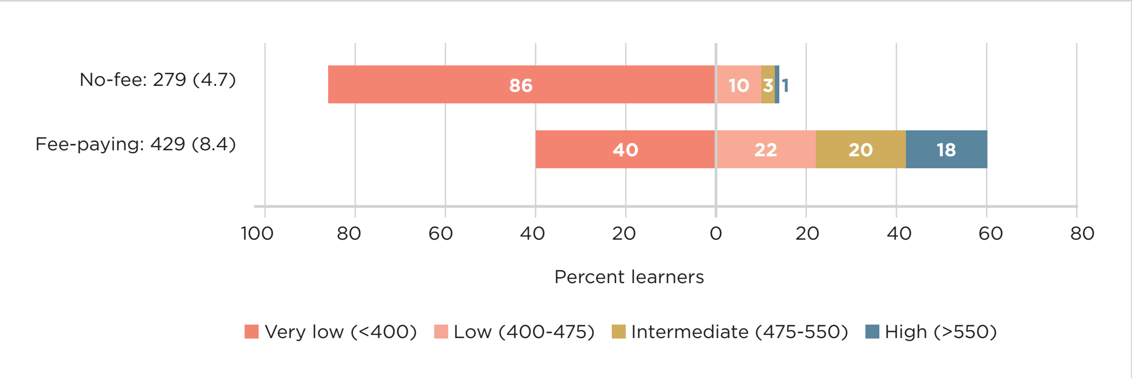
Government subsidises the school fees for learners in Quintile 1, 2 and 3 schools, which are called 'no-fee' schools (see Reader's Guide). Learners in Quintile 4 and 5, and independent schools pay fees, and their schools are designated as 'fee-paying'. Two-thirds of Grade 5 learners attended no-fee schools and one-third attended 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 achievements. In 2019, the average science score for learners in no-fee schools was 279 points and in fee-paying schools it was 429 points. This means a science achievement gap of 150 points between learners attending no-fee and fee-paying schools. The achievement gap for science of 150 points was higher than for mathematics with an achievement gap of 105 points. The wider achievement gap for science was due to the much lower average science scores, compared to mathematics scores, in no-fee schools.

Figure 13 describes the percentage of learners reaching the different international benchmarks by school fee-status. The percentage of learners to the right of the '0' point had reached the low benchmark and thus acquired the basic knowledge and skills for Grade 5 (scoring 400 points or more), while the percentage of learners to the left of the '0' point had not acquired basic scientific knowledge and skills. When the achievement scale scores are described in terms of ability levels, three in five learners (60%) in fee-paying schools reached the Low International Benchmark and demonstrated that they had acquired basic scientific knowledge and skills. It is noteworthy that 18 percent of science learners in fee-paying schools achieved scores above the High International Benchmark of 550 points. These learners had the ability to apply their understanding of science concepts to everyday and abstract situations.

In no-fee schools, on the other hand, learner performance was very concerning. One in seven learners (14%) showed that they had acquired basic scientific knowledge and skills. This means that 86 percent of learners in no-fee schools had not acquired the basic knowledge and skills for their grade.

Figure 13: Average science scale score and percentage of learners reaching international achievement benchmarks, by school fee-status



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

In the infographic that follows, we provide a summary of the science achievement and achievement gaps in Grade 5 TIMSS 2019.

3.3. SUMMARY: SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Science performance

South Africa measured science achievement in Grade 5 for the first time in TIMSS 2019. South Africa was one of the lower performing countries from the set of TIMSS 2019 participating countries. The average science scale score of 324 (4.9) was well below the TIMSS centrepoint of 500 points.

Just over a quarter (28%) of science learners demonstrated that they had acquired basic content knowledge and skills. In contrast, 72 percent of learners did not exhibit mastery of basic science knowledge. It is noteworthy that six percent of Grade 5 South African learners reached the higher international benchmarks, meaning that they were able to apply their knowledge and understanding to solve problems.

Furthermore, the average science achievement score was half a standard deviation lower than the average mathematics achievement score.

Science achievement inequality

The achievement distribution inequality, i.e. the achievement difference between the 5^{th} and 95^{th} percentiles, in the 2019 cycle, was 434 points for science. This high inequality, the biggest of all participating countries, reflects that there were a few learners performing at the highest levels and many learners achieving very low scores.

Provincial science achievements

The best performing provinces for science were the Western Cape, Gauteng and the Free State; while the lowest performing provinces were Mpumalanga and Limpopo. The provincial science achievement gap between the highest and lowest performing provinces was 141 points.

Science performance by socioeconomic status of the school

The average science score for learners in no-fee schools was 279 (4.7) and in fee-paying schools it was 429 (8.4). The achievement gap between no-fee and fee-paying schools was 150 points for science. One in seven learners (14%) in no-fee schools had acquired basic scientific knowledge and skills compared to three in five learners (60%) in fee-paying schools.

The average science achievement scores for learners in Quintile 5 and independent schools was not statistically different.

There is a continuity of disadvantage from home to schools. The achievement difference between the learners from affluent and less resourced homes begins early.

The next chapter focuses on an analysis of the Grade 5 mathematics and science curricula.

SECTION C
THE CURRICULUM

The National Curriculum Statement (NCS) Grades R to 12 stipulates the South African 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 for each schooling phase (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 documents for mathematics and science in the Intermediate Phase. 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 and topic area, as well as the extent of curriculum overlap between the TIMSS and CAPS;
(ii) Achievement and achievement gaps by cognitive domain; and
(iii) Achievement and achievement gaps by question type.

We use classical test theory (percent correct of an item) and item response theory (IRT) and plausible values 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 needed 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 assessment items are organised around two dimensions: a content domain describing the subject matter to be assessed, and a cognitive domain describing the thinking processes that learners use as they engage with the content. This allows learner performance to be described from both the content and cognitive dimensions (TIMSS 2019 Assessment Frameworks)[12].

We first report our findings for mathematics, and then for science.

4.1. MATHEMATICS CURRICULUM

Learners are introduced to numeracy from Grade R, the reception year, and mathematics remains a key subject throughout the schooling years. The CAPS for the Intermediate Phase (Grade 4 to 6) outlines the **mathematical skills** a learner should be acquiring, and the content areas covered in the curriculum (DBE, 2011a) (Annexure 2).

Performance by mathematics content and cognitive domains

The TIMSS Intermediate Phase mathematics assessment (taken at Grade 4 or 5) comprised of 171 items. Approximately half of these items appeared in previous TIMSS cycles, which allowed for a trend measure. The remaining half were newly introduced for the TIMSS 2019 cycle. South Africa, with 10 other countries, participated in the less difficult mathematics assessment (see Chapter 1 section on TIMSS Design and Methodology, and the Reader's Guide).

Achievement by content domain

TIMSS 2019 assessed three content domains in Intermediate Phase mathematics. Fifty percent of the assessment items were devoted to the **number** domain, 30 percent to the **measurement and geometry** domain, and the remaining 20 percent to the **data** 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 88 percent of the TIMSS mathematics items were taught before learners took the test. The degree of overlap between the TIMSS and South African curriculum was highest for data (96%) followed by number (94%), while for the measurement and geometry content domain the overlap was 79 percent.

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

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

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

	Percent match between TIMSS and CAPS	Mathematics scale score (SE)	Difference from national mean score
National: All mathematics items (171 items)	88	374 (3.6)	
Number (83 items)	94	370 (3.6)	-4 points*
Measurement and Geometry (52 items)	79	362 (3.7)	-12 points*
Data (36 items)	96	390 (3.8)	+16 points*

* Statistically significant achievement difference from national mean score.

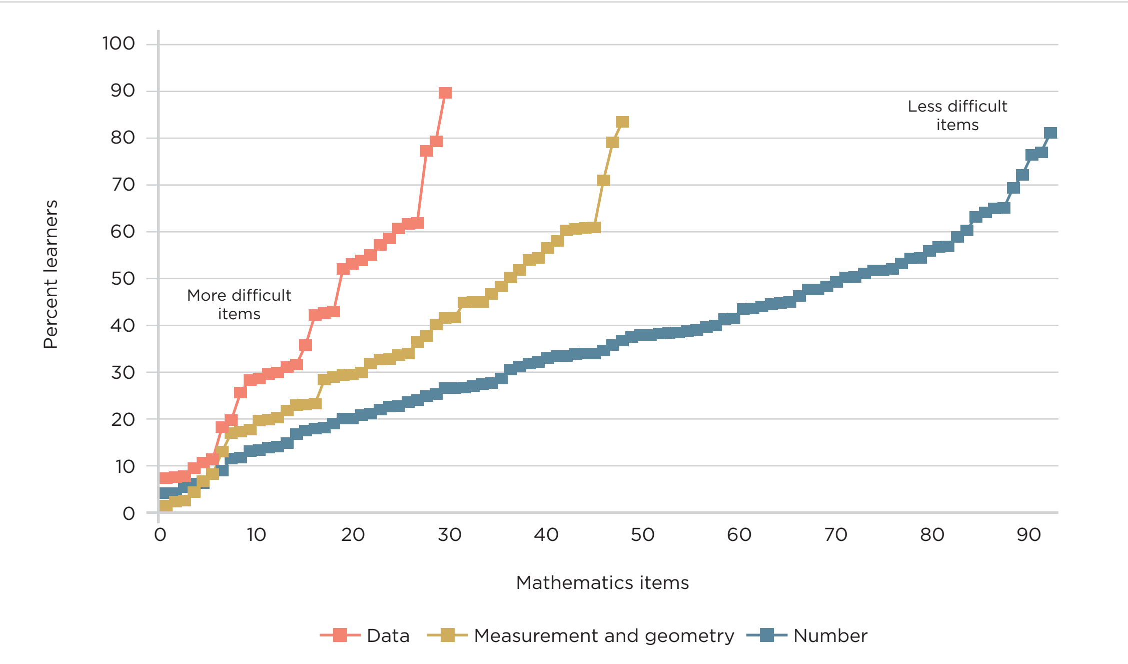
Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

Next, we plotted a graph of the percentage of learners that gave the correct responses for each item, in each of the three content domains, and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 14.

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 percent correct, are on the right-hand side.

This is followed by the table of average percent correct for South Africa and the 11 countries that participated in the TIMSS less difficult mathematics assessment, for each of the domains. A higher percentage of learners provided correct responses to items in the data content domain (average of 40% correct), while learner performance for number (35%), and measurement and geometry (34%) was similar. The patterns on the average percentage correct resonate with the scale scores for each of the content domains, confirming that learners have more difficulty in the areas of measurement and geometry, and number.

Figure 14: Percentage of Grade 5 learners who answered mathematics items correctly per content domain

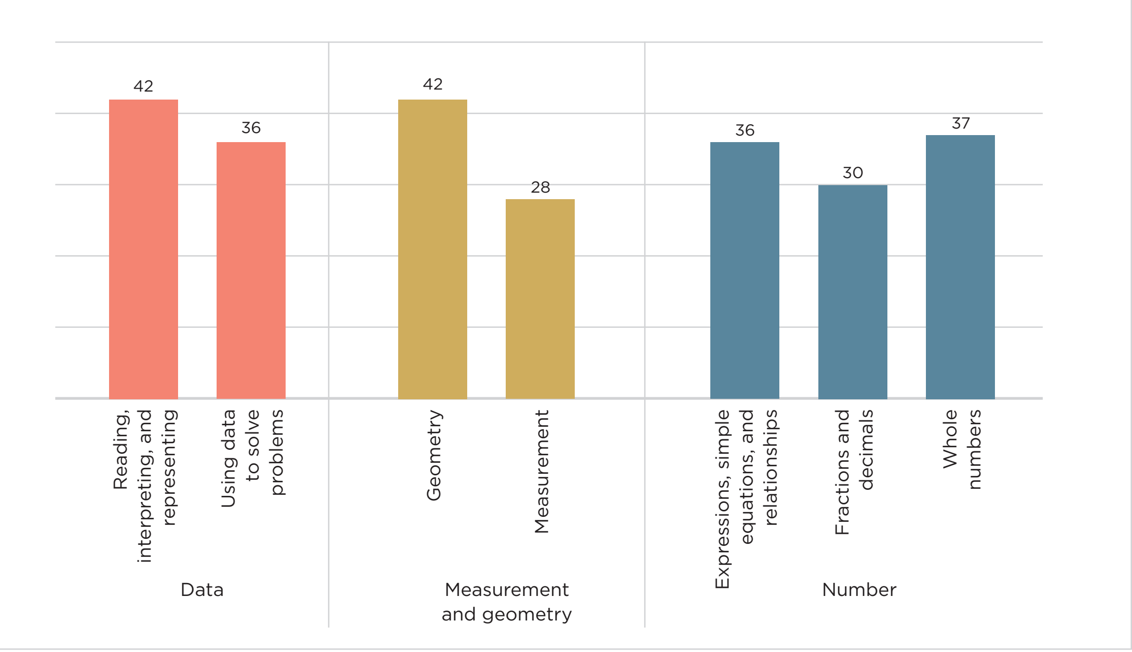


	All Items	Data	Measurement and Geometry	Number
Average South African percent correct	36	40	34	35
TIMSS Less Difficult Mathematics international percent correct (11 countries)	43	42	41	44

Source: Mullis et al. (2020) TIMSS 2019 International Results in Mathematics and Science.

The content domains were further disaggregated into seven mathematics topic areas. The percentage of learners that correctly answered items in each topic area is reported in Figure 15. Learners performed best in the topic areas of geometry (42%), and reading, interpreting and representing data (42%), while the average for whole numbers was 37 percent and for expressions, simple equations and relationships, and using data to solve problems it was 36 percent. The lowest percentages correct were for measurement (28%), and fractions and decimals (30%) items.

Figure 15: Mathematics topic areas and the average percent correct



Source: TIMSS 2019 South African Grade 5 dataset.

Achievement by cognitive domain

TIMSS differentiates the achievement items into three hierarchically organised cognitive domains: knowing, applying and reasoning. In the TIMSS less difficult mathematics assessment, 45 percent of items were classified as knowing, while 55 percent of the items were at the higher cognitive levels of 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 each cognitive domain and the average mathematics scale score for each domain. The average mathematics scale score for knowledge items and applying items was not significantly different from the national average mathematics score, while on reasoning items, learners scored a statistically significant 4 points lower than the national average.

Table 7: Average mathematics achievement by TIMSS cognitive domain

	Percent items in the TIMSS Less Difficult Curriculum	Mathematics scale score (SE)	Difference from national mean score
National: All mathematics items (171 items)	100	374 (3.6)	
Knowing (77 items)	45	372 (3.7)	-2 points
Applying (60 items)	35	375 (3.6)	+1 points
Reasoning (46 items)	20	370 (3.8)	-4 points*

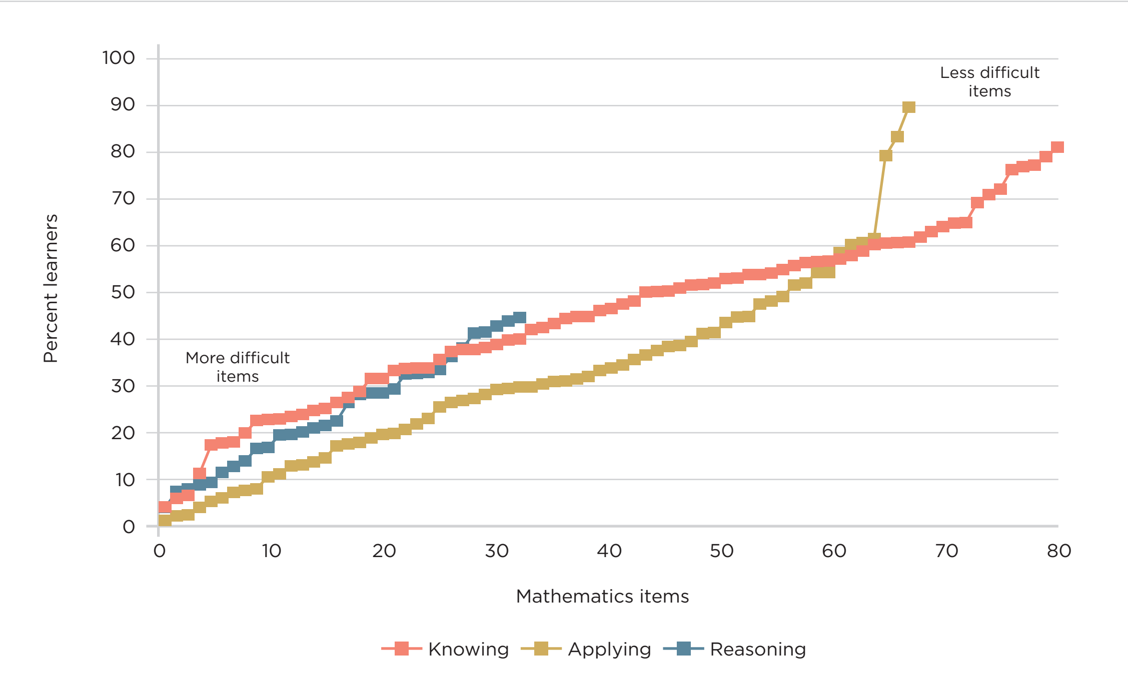
* Statistically significant achievement difference from national mean score.

Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

Next, we plotted the percentage correct 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 16. This is followed by the table of average percent correct for South Africa and the countries that participated in the TIMSS less difficult mathematics assessment, for each of the domains.

The average percentage correct was highest for the knowing cognitive domain (average of 45% correct), followed by applying (33%) and then reasoning (23%). While more learners answered knowing items correctly, when this was combined with the difficulty level of these items, the achievement scale score for the knowing domain was slightly lower than the overall average.

Figure 16: Percentage of Grade 5 learners who answered mathematics items correctly per cognitive domain



	All Items	Knowing	Applying	Reasoning
Average South African percent correct	36	45	33	23
TIMSS Less Difficult Mathematics international percent correct (11 countries)	43	51	40	30

Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

4.2. 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) (See Annexure 2).

Performance by science content and cognitive domains

The TIMSS Intermediate Phase science assessment (taken at Grade 4 or 5) consisted of 169 items. Approximately half of these items appeared in previous TIMSS cycles, which allowed for a trend measure. The remaining half were newly introduced for the TIMSS 2019 cycle. South Africa participated in the same Grade 5 science assessment as all other countries.

Achievement by content domain

TIMSS 2019 assessed three content domains, in Intermediate Phase science: Earth science, life science and physical science. Twenty percent of the assessment items were devoted to Earth science, 45 percent to life science, and the remaining 35 percent to physical science.

Table 8 reports the South African Grade 5 results for the science content domains 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 80 percent of the TIMSS science items was 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 life science (88%), followed by Earth science[13] (78%) and then physical science (76%).

We must treat the average science score estimates by content domain cautiously. There are reservations about the reliability of the estimates because the percentage of learners with achievement too low for estimation exceeded 25 percent (see Mullis et al., 2020: 575). Given the low reliability of the score estimates, we provide the content area score estimates for illustrative purposes only and will not draw any comparisons among them.

Table 8: Average science achievement by content domain, and match between TIMSS and CAPS curriculum

	Percent match between TIMSS and CAPS	Science scale score (SE)
National: All science items (169 items)	80	324 (4.9)
Life science (73 items)	88	322 (5.3)
Physical science (61 items)	76	308 (5.2)
Earth science (35 items)	78	312 (5.5)

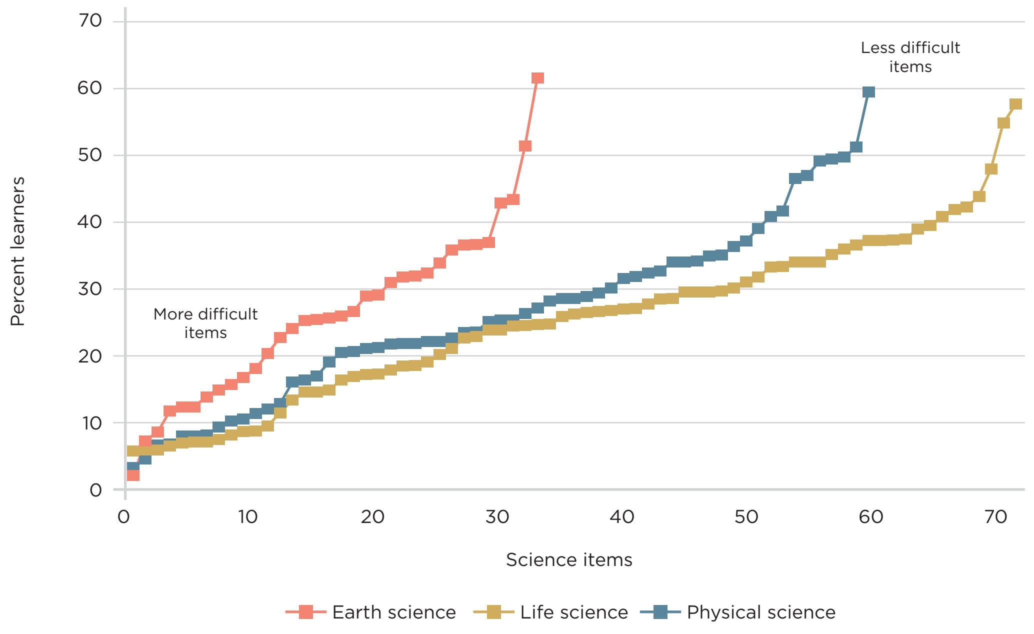
Source: Preliminary TIMSS 2019 International Results in Mathematics and Science (not included in the final report).

Next, we plotted a graph of the percentage of learners that gave correct responses for each item, in each of the three content domains, and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 17 (See Reader's Guide for Item Percent Graphs). This is followed by the table of average percent correct for South Africa and the 28 countries that participated in paper TIMSS for the science assessment, for each of the domains.

The average percent correct for the content domains were similar to each other: items in Earth science and physical science had an average of 26 percent correct, and life science had an average of 24 percent correct.

13 In the South African curriculum, Earth science topics are taught in both the natural sciences and social science subject areas.

Figure 17: Percentage of Grade 5 learners who answered science items correctly per content domain

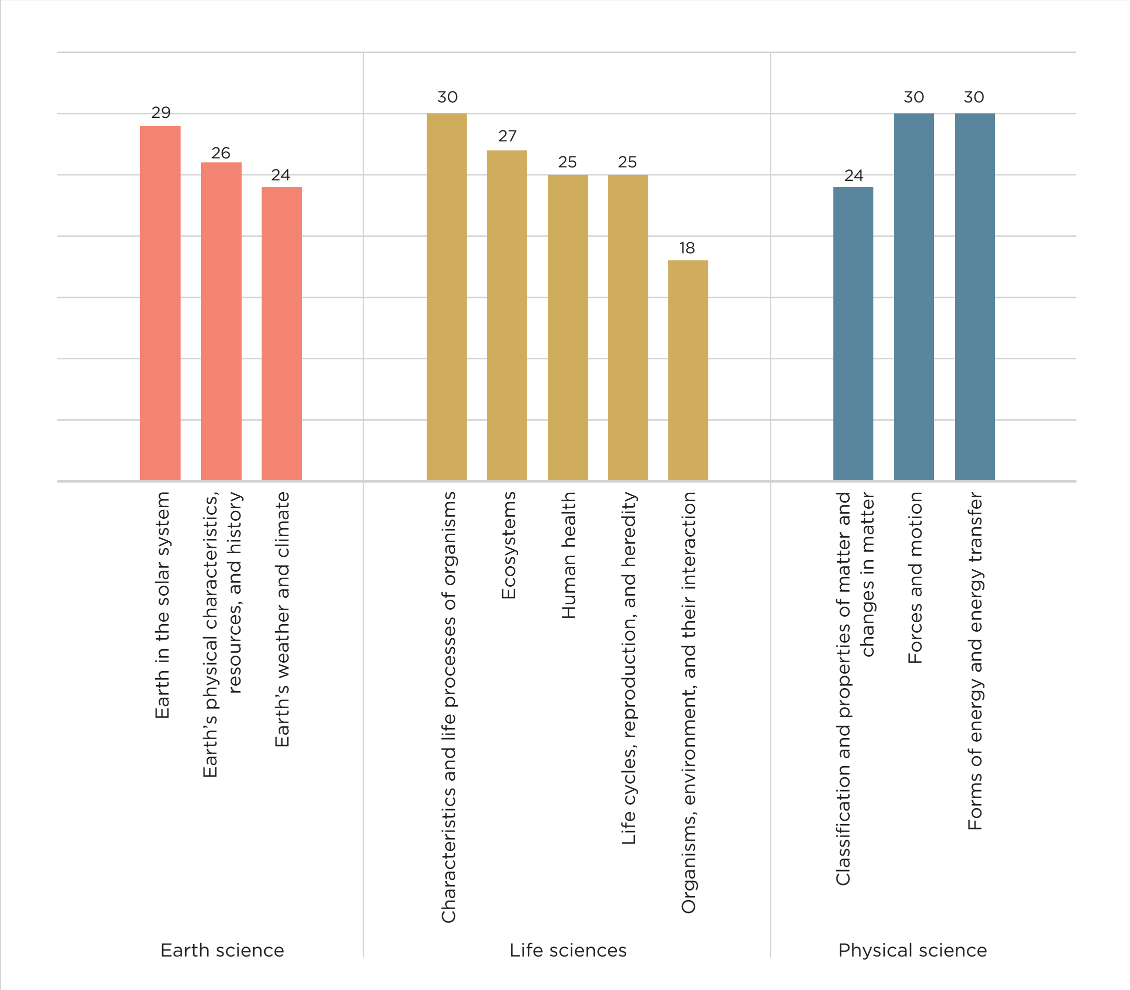


	All items	Life science	Physical science	Earth science
Average South African percent correct	25	24	26	26
Paper TIMSS international percent correct (28 countries)	43	41	45	41

Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

The content domains were further disaggregated into 12 science topic areas. We calculated the average percent correct for each of these topic areas. The topic areas and the average percent correct for items in each topic are noted in Figure 18. Learners performed best in the topic areas of characteristics and life processes of organisms (30%), forces and motion (30%), and forms of energy and energy transfer (30%). They performed lowest in the topic areas of classification and properties of matter and changes in matter (24%), Earth's weather and climates (24%) and organisms, environment, and their interactions (18%).

Figure 18: Science topic areas and the average percent correct



Source: TIMSS 2019 South African Grade 5 dataset.

Achievement by cognitive domain

TIMSS differentiates the achievement items into three hierarchically organised cognitive domains: knowing, applying, and reasoning (refer to Reader's Guide). In the TIMSS 2019 science assessment, 40 percent of items were classified as knowing, and 60 percent 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 each cognitive domain and the average science achievement score for each domain. Again, we must treat the science score estimates cautiously because the percentage of learners with achievement too low for estimation exceeded 25 percent (See Mullis et al., 2020: 575). Given the low reliability of the score estimates, we will not comment on the achievement scores for each of the cognitive areas and present the results for illustrative purposes only.

Table 9: Average science achievement by TIMSS cognitive domain

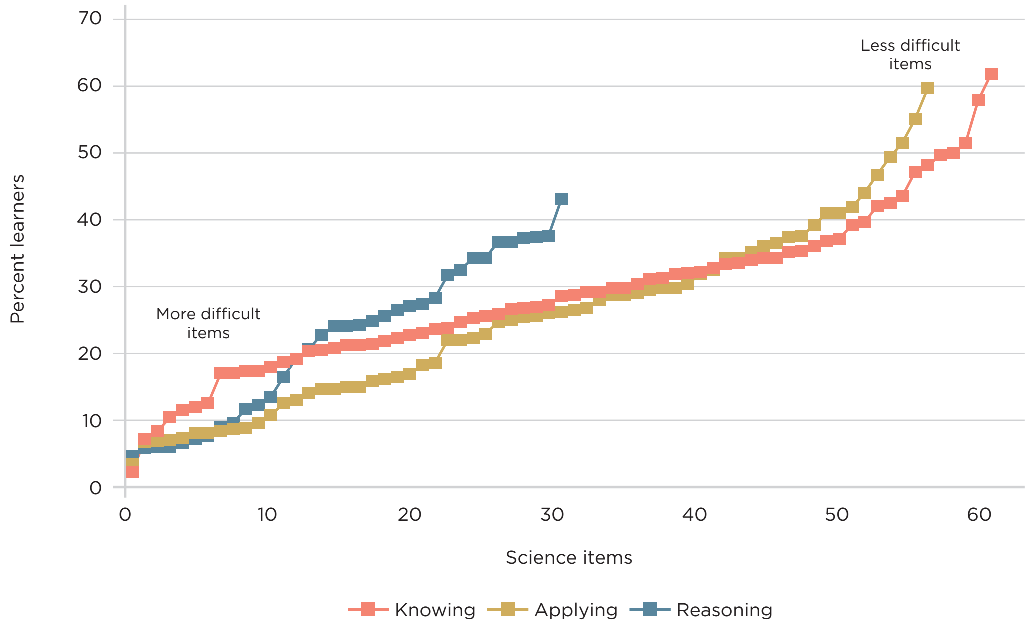
	Percent items in TIMSS curriculum	Science scale score (SE)
All science items (169 items)	100	324 (4.9)
Knowing (69 items)	40	313 (5.8)
Applying (64 items)	37	321 (5.3)
Reasoning (36 items)	21	315 (5.6)

Source: Preliminary TIMSS 2019 International Results in Mathematics and Science (not included in the final report).

We plotted the percentage of learners that 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 19 (See Reader's Guide). This is followed by the table of average percent correct for South Africa and the countries that participated in paper TIMSS for the science assessment, for each of the domains.

The average item percent correct for the cognitive domains of knowing and applying was higher than the average item percent correct for reasoning items.

Figure 19: Percentage of Grade 5 learners who answered science items correctly per cognitive domain



	All Items	Knowing	Applying	Reasoning
Average South African percent correct	25	27	25	21
Paper TIMSS international percent correct (28 countries)	43	46	43	37

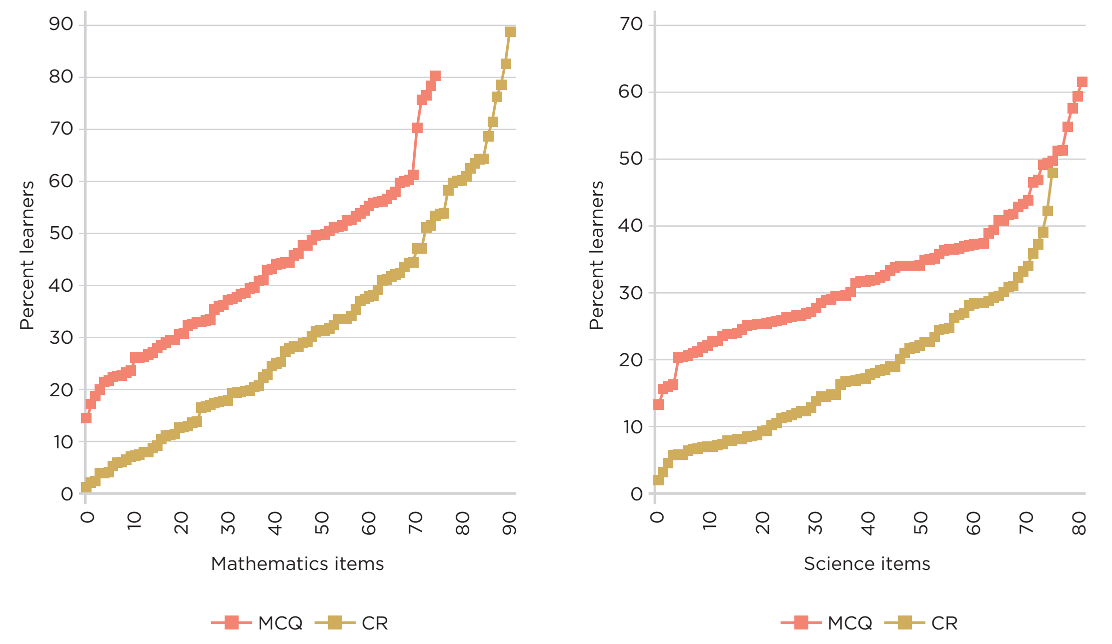
Source: Mullis et al. (2020). TIMSS 2019 International Results in Mathematics and Science.

4.3. 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 (CR). 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.

We calculated the percentage of learners that responded correctly to each of the selected and constructed response items. The graphs are shown in Figure 20, along with the percentage of correct responses for mathematics and science items in both formats.

Figure 20: Percentage of Grade 5 learners who answered mathematics and science selected response (MCQs) and constructed response (CR) items correctly



	Less Difficult Mathematics average percent correct	Science average percent correct
Selected Response Items (MCQs)	42	33
Constructed Response Items (CR)	32	18

Source: TIMSS 2019 South African Grade 5 dataset.

Learners performed better on items requiring a selected (multiple choice) response (42 percent for mathematics and 33 percent for science answered these items correctly), than on items where learners had to construct a response (32 percent of items correct for mathematics and a very low 18 percent for science). Analysis of learner responses, during the item scoring process, 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 mathematics and science achievement in TIMSS 2019 by content domain, cognitive domain, and question type.

4.4. SUMMARY: MATHEMATICS AND SCIENCE CURRICULA

Achievement by mathematics content domains

The content of close to 90 percent 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 data (96%), followed by number (94%), and measurement and geometry (79%).

For the mathematics content domains, the average score for the data domain was significantly higher than the national average score, while in the geometry and measurement, and number domains, was significantly lower average scores than the national average score.

Learners performed best in the geometry items, followed by reading, interpreting and representing data. The lowest performance was on measurement, and fractions and decimal items.

Achievement by science content domains

The content of 80 percent of the TIMSS science items was reported to have been taught at school before learners took the test. The degree of overlap between the TIMSS and South African science curriculum was highest for life science (88%), followed by Earth science (78%) and then physical science (76%).

Grade 5 science achievement was very low, so we must view scale score estimates for the sub-groups cautiously.

Learners performed best in the topic areas of characteristics and life processes of organisms; forces and motion; and forms of energy and energy transfer; and lowest in Earth's weather and climates; and organisms, environment, and their interactions.

Achievement by mathematics and science cognitive domains

TIMSS differentiates the achievement items into three hierarchically organised cognitive domains: knowing, applying and reasoning. In TIMSS 2019, 45 percent of the mathematics less difficult items and 40 percent of the science assessment were classified as knowing, and the remainder of the items were at the higher cognitive levels of applying and reasoning.

The average mathematics scale score for reasoning items was significantly lower than the overall average national mathematics scale score, whereas the scale score for knowledge and applying items was not significantly different from the national average score.

Given the low science achievement scores, with the high levels of very low scores making estimates for the cognitive categories unreliable, we cannot comment on the average achievement scores by cognitive domains.

Achievement by question type

As would be expected, learners performed better on items requiring a multiple choice response and had greater difficulty on items where they had to construct an explanation or make an argument. The performance on the science constructed items was particularly poor and much lower than that for mathematics items.

The next chapter presents findings related to Grade 5 learners' individual characteristics and their attitudes to learning mathematics and science.

SECTION D

LEARNER CHARACTERISTICS AND HOME ENVIRONMENTS 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 observed differences in achievement are associated with individual, home, classroom and school characteristics.

Section D first reports on learner characteristics and attitudes, and then on home socioeconomic status and early learning preparations, and their relationship with achievement. In order to capture the context in which learners live and learn, learners completed a Learner Questionnaire and parents completed an Early Learning Survey. The Learner Questionnaire included demographic, school safety and support for learning at home items, as well as items related to attitudes to mathematics and science and classroom activities related to mathematics and science learning. The Early Learning Survey collected information about parents' demographics, as well as their education levels and occupations, early numeracy and literacy activities that took place at home before their child began primary school and home support for learning.

This section consists of two chapters:

(i) Chapter 5 focuses on two aspects: (i) Learner characteristics of gender, language spoken at home and age, and the relationship with achievement; and (ii) Learner attitudes towards mathematics and science and the relationship with achievement.

(ii) Chapter 6 examines (i) Learners and their home environment, i.e. home assets, educational resources, and support for learning, and the relationship with achievement; and (ii) Early learning educational activities focusing on the frequency of engaging in these activities, pre-school attendance including Grade R and an assessment of early literacy and numeracy skills.

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. Regarding the latter, there is the proviso that there are high standard errors, as there are a smaller number of participating independent schools in the sample. Due to the small number of independent schools, we largely combine the group of public fee-paying and independent schools to report on fee-paying schools.

CHAPTER FIVE

LEARNER CHARACTERISTICS AND ATTITUDES

There are many ways in which a learner's individual characteristics and attitudes to learning mathematics and science are related to achievement outcomes. This chapter first reports on the individual level characteristics of learners' gender, language spoken at home, and age, and the relationship with mathematics and science achievement. We then report on learner attitudes, focusing on the attitudes of enjoying ('Like Learning') mathematics and science and confidence in their abilities, and the relationship with achievement.

5.1. A PROFILE OF LEARNERS

Learners' gender and achievement

International evidence on the relationship between gender and achievement is fairly mixed, not only across countries, but also within countries (Mullis et al., 2020). The general pattern of gender gaps in educational achievement is that girls outperform boys in reading and boys outperform girls in mathematics and the sciences. Recent analysis using TIMSS datasets, with a more diverse set of countries than in the past, reveals that in Middle Eastern and lower income countries, girls outperformed boys in both the 4th and 8th grades in mathematics and science (Ghasemi & Burley, 2019).

Gender differences in educational experiences in South Africa are complex and multi-dimensional and intersect with race and socioeconomic status. The Department of Basic Education's (DBE) *Action Plan to 2024* (2020a) highlights its concern regarding the poor performance of boys and seeks a better understanding, as well as remediation measures inside and outside the classroom.

At Grade 5, girls and boys each make up 50 percent of the learner cohort. We examined the gender achievement patterns for South Africa, as well as in the contexts of higher and lower economic affluence by using the fee-status of the school to differentiate levels of affluence.

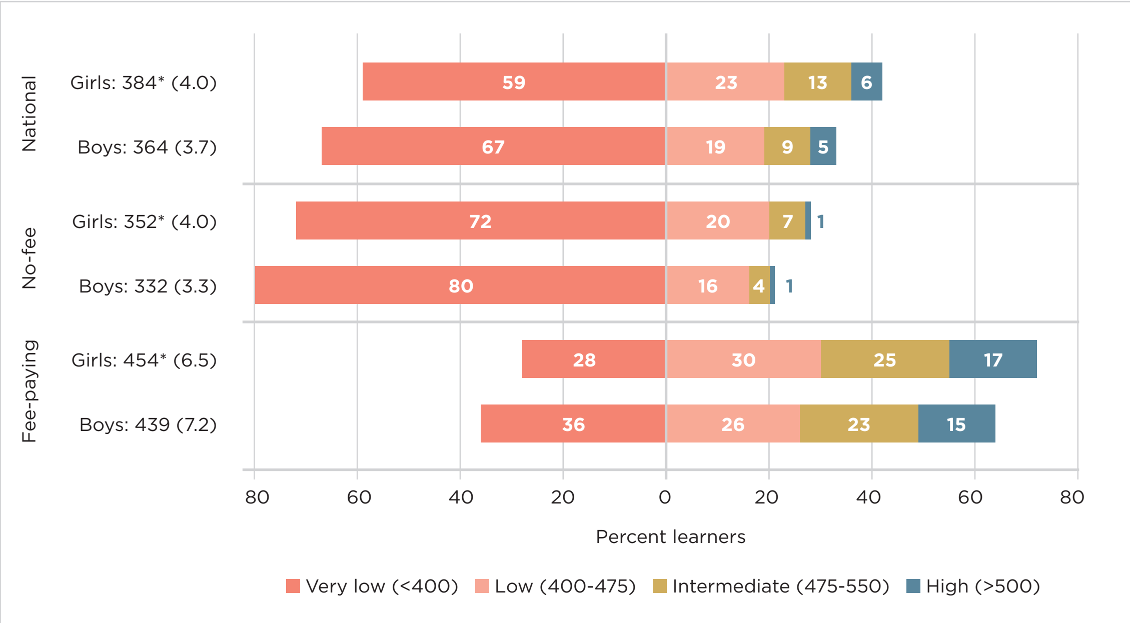
Mathematics achievement by gender

Among the 58 TIMSS countries participating at Grade 5, girls achieved significantly higher mathematics scores in four countries (the Philippines, Saudi Arabia, South Africa and Oman), there was no significant gender difference in achievement in 27 countries, and boys had significantly higher mathematics achievement than girls in 27 countries.

The South African mathematics achievement scores and international achievement benchmarks, for girls and boys nationally, and for fee-paying and no-fee schools are presented in Figure 21. The average mathematics achievement score for girls was 384 (4.0), which is higher than for boys at 364 (3.7). This 20-point difference was statistically significant.

Girls outscored boys by a statistically significant 20 points in no-fee schools and a statistically significant 15 points in fee-paying schools. In both cases more girls than boys had acquired the basic mathematical knowledge and skills.

Figure 21: Average mathematics scale score and percentage of learners reaching international achievement benchmarks, by school fee-status and gender



* Statistically significant achievement difference between boys and girls.

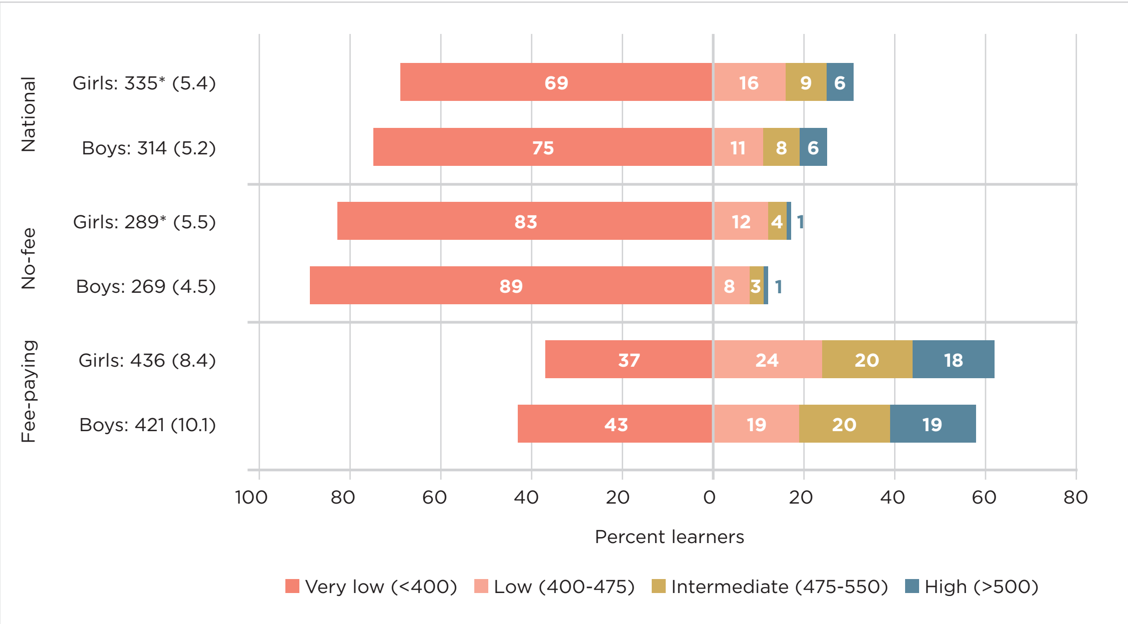
Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Science achievement by gender

Among the TIMSS countries participating at Grade 5, girls achieved significantly higher science scores in 18 countries, including South Africa. There was no gender achievement difference in 33 countries and boys had significantly higher achievement scores than girls in seven 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 22. Nationally, the average scale score for girls of 335 (5.4) was significantly higher, by 21 points, than for boys at 314 (5.2). Girls significantly outscored boys in no-fee schools by 20 points, but in fee-paying schools the score difference of 15 points was not statistically significant.

Figure 22: Average science scale score and percentage of learners reaching international benchmarks, by school fee-status and gender



* Statistically significant achievement difference between boys and girls.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

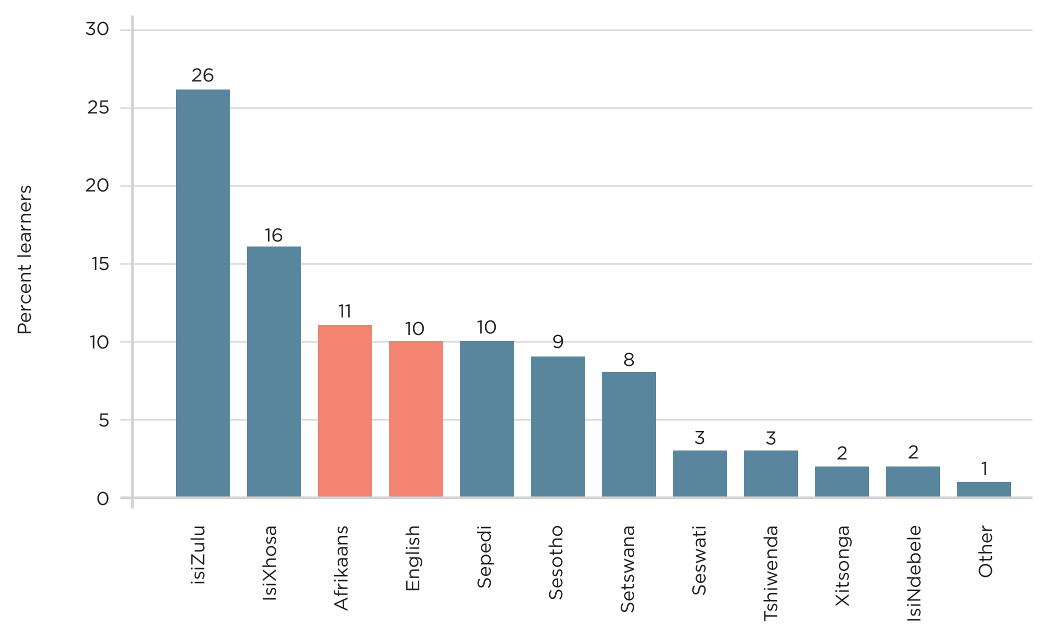
Learners' linguistic characteristics and achievement

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 South African Constitution (RSA, 1996a). Figure 23 presents the language most often spoken at home as reported by learners. isiZulu was the most common language spoken at home (26%), followed by isiXhosa (16%). 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 reported to be spoken by 10 percent and 11 percent of learners at home, respectively.

Figure 23: Home languages of learners



Source: TIMSS 2019 South African Grade 5 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 in the language of teaching, learning, and assessment provides access to the learning process. Language proficiency has been shown to be related to learning and achievement scores (Prinsloo, Rogers & Harvey, 2018). The Progress in International Reading Literacy Study (PIRLS) assessed reading comprehension, in the 11 official South African languages, at Grade 4. The results estimated that three in four (78%) learners could "not read for meaning or retrieve basic information from the text to answer simple questions" (Howie et al., 2017).

The debate around the relationship between home language, the LoLT and academic performance is not straightforward. As pointed out in DBE's *Action Plan to 2024* (2020a: 24), the way in which the official languages are used in the classroom has major implications for learning. In general, learners who speak one of the indigenous African languages at home generally experience a triple disadvantage: they have to begin learning a new, unfamiliar language in Grade 4; they come from more socioeconomically disadvantaged households; and they are more likely to experience poor language teaching.

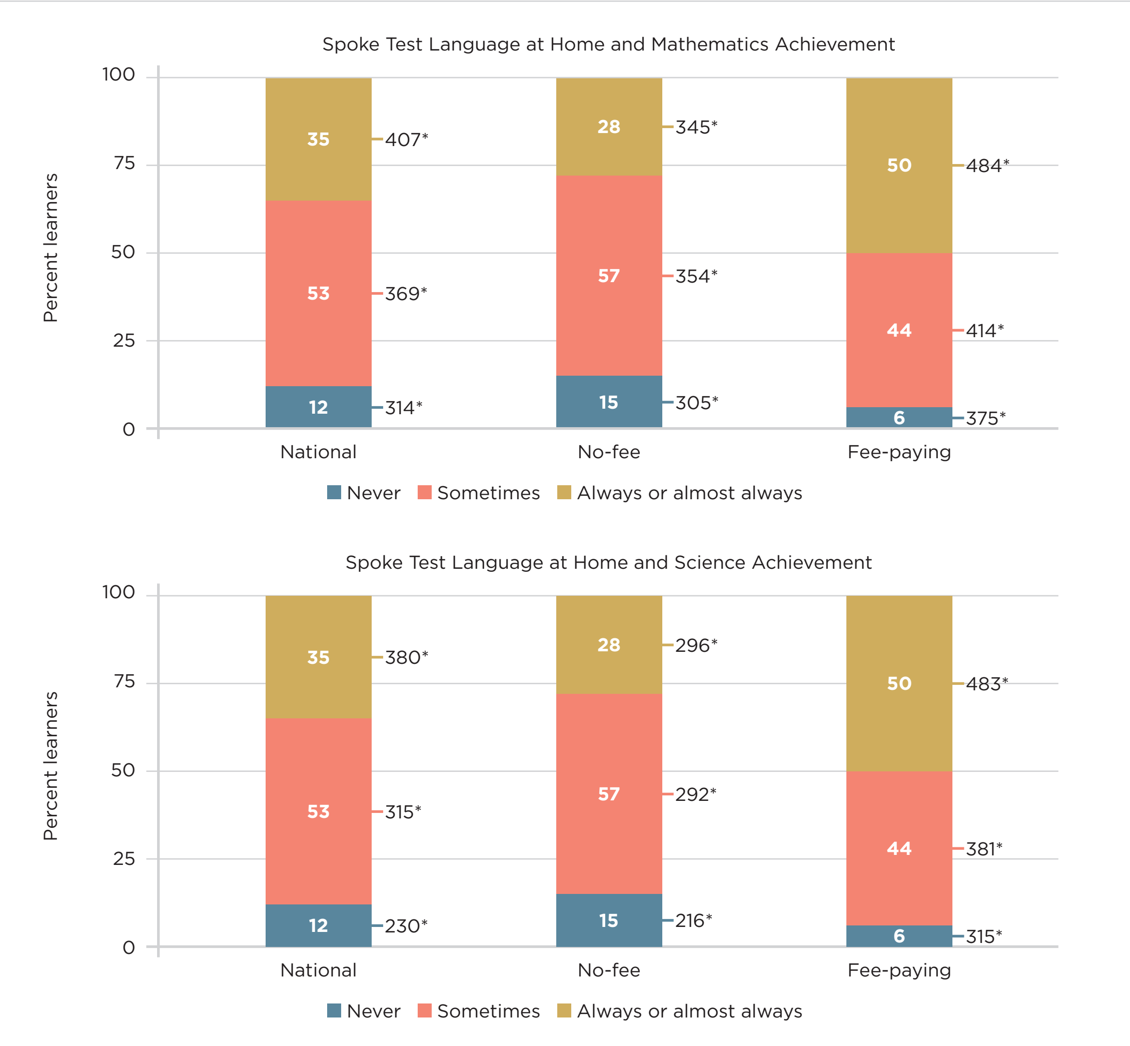
In TIMSS 2019, learners reported the extent to which they spoke the language of the test at home (Figure 24). This response was used here as a proxy for the ability of learners to read and understand the TIMSS items.

Thirty-five percent of learners reported that they 'always or almost always' spoke the language of the test at home, 53 percent 'sometimes' spoke it, and 12 percent 'never' spoke the language of the test at home. This pattern was different in the fee-paying and no-fee schools. One in four learners (28%) in no-fee schools, in comparison with one in two learners (50%) 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 (407 versus 314 for mathematics, and 380 versus 230 for science). The achievement difference between those who frequently spoke the language of the test at home and those who never did was 93 points for mathematics and a much higher 150 points 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 school, were at an advantage. The analysis also signals that language effects have a greater impact on science achievement in comparison to mathematics achievement.

Figure 24: Percentage of learners speaking the language of the test at home and achievement, by school fee-status



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

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

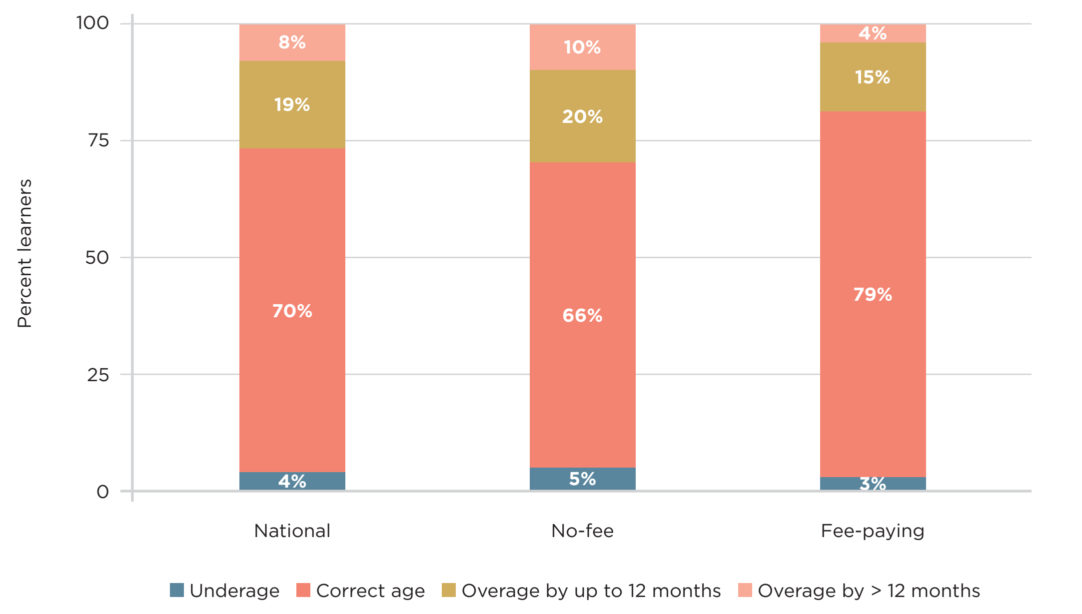
Age of learners and achievement

The average age of Grade 5 South African learners in the TIMSS 2019 cohort, at the time of administration, was 11.5 years. Girls were younger than boys, with an average age of 11.4 years, compared to an average age for boys of 11.7 years.

We investigated the extent of overaged learners in South Africa in the TIMSS cohort. Grade 5 learners who started school at the correct age, and who progressed through school without repeating a grade or experiencing other interruptions, would have been aged between 10.3 and 12 years at the time of the 2019 TIMSS administration. We then categorised other learners as either underage or overage[14]. Figure 25 reports the age distribution of learners for South Africa, and for no-fee and fee-paying schools.

Nationally, 27 percent of Grade 5 learners were overage. This pattern was different in no-fee and fee-paying schools where 30 percent and 19 percent of learners, respectively, were overage. Learners could have been overage due to starting school late, dropping in and out of school, or repeating a grade.

Figure 25: Age distribution of TIMSS 2019 cohort, by school fee-status



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Next, we explored the relationship between the learners' age and their achievement scores (Table 10). Learners who were the correct age for Grade 5 achieved significantly higher mathematics and science scores than those who were overage (393 versus 301 for mathematics, and 349 versus 229 for science). The oldest learners achieved the lowest scores.

14 Underage learners were younger than 10.3 years; correct age learners were aged between 10.3 and 11.99 years; learners that were overage by up to 12 months were aged 12.0 to 12.99 years; and learners that were overage by more than 12 months were aged 13.0 years or above in 2019.

Table 10: Learner achievement in mathematics and science by age distribution

Age category			Mathematics Mean (SE)	Science Mean (SE)
Underage	On track	4	355 (6.3)	299 (7.1)
Correct age	On track	70	393 (3.7)	349 (5.2)
Overage by up to 12 months	+ 1 year	19	339 (4.1)	280 (5.5)
Overage by more than 12 months	+ 2 years	8	301 (4.1)	229 (5.7)
National average		**100**	**374 (3.6)**	**324 (4.9)**

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

5.2. LEARNER ATTITUDES TOWARDS MATHEMATICS AND SCIENCE

There is a long-standing interest on how non-cognitive factors, such as personality, attitudes, and social and emotional traits are related to achievement (Heckman, 2006; Cunha, Heckman & Schennach, 2010). The South African Curriculum and Assessment Policy Statements (CAPS) also embrace the role of non-cognitive outcomes for mathematics and science (Annexure 3). 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 towards mathematics and science have higher average achievement in those subjects. While positive attitudes and higher mathematics and science achievement go hand in hand, it should be understood that the relationship is bidirectional, with attitudes and achievement mutually reinforcing each other.

TIMSS 2019 measured learner attitudes towards mathematics through two scales: *Learners Like Learning Mathematics* and *Learners Confident in Mathematics*, with equivalent scales in science measuring similar constructs.

Learners like learning mathematics and science

The *Learners Like Learning Mathematics* and *Learners Like Learning Science* scales measured learners' intrinsic motivation to learn the subjects. Learners who are intrinsically motivated to learn mathematics or science find the subject to be interesting and enjoyable (Winberg & Palm, 2021). Previous TIMSS data have shown a strong relationship between the liking scales and learner achievement. Table 11 reports the learners' agreement (agreeing a lot) with a set of statements related to their liking learning mathematics and science.

Overall, many learners expressed strong positive attitudes towards learning mathematics and science.

Table 11: 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 enjoy learning mathematics	75	I enjoy learning science	73
I like mathematics	72	I like science	67
I learn many interesting things in mathematics	67	I learn many interesting things in science	66
Mathematics is one of my favourite subjects	64	Science is one of my favourite subjects	57
I like any schoolwork that involves numbers	63	I look forward to learning science in school	63
I like to solve mathematics problems	61	Science teaches me how things in the world work	70
I look forward to mathematics lessons	60	I like to conduct science experiments	63
I wish I did not have to study mathematics	23	I wish I did not have to study science	22
Mathematics is boring	18	Science is boring	19

Source: TIMSS 2019 South African Grade 5 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[15]. On this scale, 46 percent of South African learners were categorised that they 'very much liked learning mathematics', which was similar to the international average of 45 percent. Forty-three percent of South African learners 'very much liked learning science', and this was slightly lower than the international average of 52 percent.

Next, we examined the association between the *Learners Like Learning Mathematics/Science* scales, and their mathematics and science achievement (Figure 26). Nationally and in no-fee schools, 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. In fee-paying schools, the relationship was not as strong, with learners who 'very much liked learning' mathematics and science achieving significantly higher mathematics and science scores than learners who 'somewhat' or 'did not like learning' mathematics or science.

Figure 26: Learners like learning mathematics or science and achievement, by school fee-status

* Statistically significant achievement differences between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

15 See Mullis et al. (2020) for a description of the Learners Like Learning Mathematics Scale (Page 428) and Learners Like Learning Science Scale (Page 431).

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*[16] *in Mathematics* and *Learners Confident in Science* scales. The results from previous TIMSS cycles have shown a strong relationship between learners' academic self-concept and their achievement. Herrera, Al-Lal and Mohamed (2020) found that self-concept was a strong predictor of academic achievement among primary school children.

Table 12 records the percentage of learners 'agreeing a lot' with statements related to their confidence in mathematics or science. Similar to their rating of items about liking learning mathematics and science, learners also responded positively to items relating to their confidence in learning mathematics and science. Despite that, a quarter of learners acknowledged that they were nervous or confused about learning mathematics and science.

Table 12: Percentage of learners who agreed 'a lot' with statements that they are confident in mathematics and science

Confident in mathematics	Percent learners Agree a lot	Confident in science	Percent learners Agree a lot
I usually do well in mathematics	64	I usually do well in science	67
I learn things quickly in mathematics	56	I learn things quickly in science	58
I am good at working out difficult mathematics problems	47	*No equivalent item for science*	
My teacher tells me I am good at mathematics	46	My teacher tells me I am good at science	47
Mathematics makes me nervous	30	*No equivalent item for science*	
Mathematics is harder for me than any other subject	29	Science is harder for me than any other subject	24
Mathematics makes me confused	28	Science makes me confused	28
Mathematics is harder for me than for many of my classmates	28	Science is harder for me than for many of my classmates	25
I am just not good at mathematics	23	I am just not good at science	23

Source: TIMSS 2019 South African Grade 5 dataset.

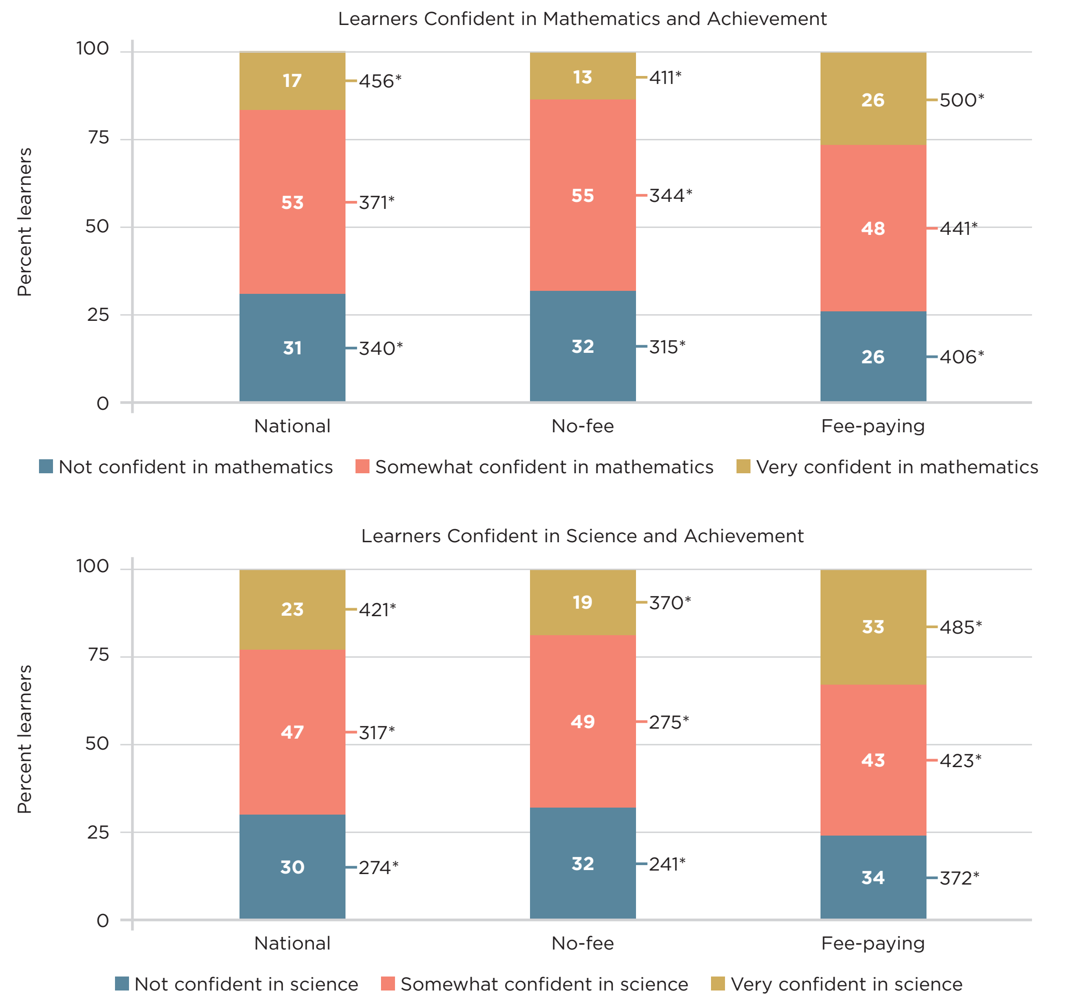
Learners were scored according to the nine statements in the *Learners Confident in Mathematics* scale, and seven statements in the *Learners Confident in Science* scale. Each scale was then divided into three categories: 1) *very confident* in mathematics/science, 2) *somewhat confident* in mathematics/science, and 3) *not confident* in mathematics/science[17]. On this scale, 17 percent of South African learners, compared to the international average of 32 percent, were categorised as 'very confident' in mathematics. Twenty-three percent of learners were 'very confident' in science, in comparison with 38 percent internationally.

Next, we examined the association between the *Learners Confident in Mathematics/Science* scales, and mathematics and science achievement. For both mathematics and science, at the national level, as well as in no-fee and fee-paying schools, there was a significant positive association between learners' level of confidence in mathematics and science, and their achievement (Figure 27).

16 Some authors, such as Bandura (1977) refer 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.

17 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 27: Learners confident in mathematics or science and achievement, by school fee-status



* Statistically significant achievement differences between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

The infographic that follows provides a summary of Grade 5 learners' individual characteristics, and their attitudes towards mathematics and science, and the relationship between these factors and achievement.

5.3. SUMMARY: LEARNER CHARACTERISTICS AND ATTITUDES

Learners' gender and achievement

South Africa was one of four countries where girls significantly outperformed boys in mathematics, and one of 18 countries where girls significantly outperformed boys in science. In South Africa, the mathematics and science scores achieved by girls was significantly higher than for boys at the national level as well as in no-fee schools. In Chapter 9, we show through multivariate analyses, that the gender advantage of girls changes when other factors are included in the model.

Learners' language proficiency and achievement

Thirty-five percent of learners (a quarter of learners in no-fee schools and half the learners in fee-paying schools) frequently spoke the language of the test at home and they had better linguistic access to the TIMSS assessments.

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. These results confirm previous studies that found that learners who frequently spoke the language of instruction, were regularly exposed to it, and used the language outside of school, were at an advantage.

Age of learners and achievement

Nationally, 27 percent of Grade 5 learners were overage (30 percent of learners in no-fee schools and 19 percent in fee-paying schools). Girls were younger than boys by an average of 0.3 years. Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage.

Learner attitudes, and mathematics and science achievement

The cross-country responses related to learner attitudes shows that learners in lower income and lower performing countries reported more positive attitudes to mathematics and science than learners in high income countries with generally higher performing learners. While positive attitudes and high achievement go hand in hand, they mutually reinforce each other with one producing advances in the other.

Learners like learning mathematics and science

Forty-six percent of mathematics learners and 43 percent of science learners reported that they very much liked learning mathematics and science respectively. Learners who liked learning mathematics and science achieved significantly higher scores than those who only somewhat liked or did not like learning these subjects. This relationship was more distinct in no-fee schools than in fee-paying schools.

Learners confident in mathematics and science

Seventeen percent of learners reported that they were very confident in mathematics, and 23 percent were very confident in 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.

In Chapter 6, we examine learners' diverse home environments and the relationship with their achievement; and explore early learning educational activities as well as early literacy and numeracy skills.

CHAPTER SIX

LEARNERS' HOMES AND THEIR EARLY LEARNING PREPARATION

The extant literature confirms that the socioeconomic status (SES) of the home is a key determinant of educational achievement as well as future educational and labour market trajectories (The World Bank, 2018). Educational inequality, which is closely linked to socioeconomic disparities, is an issue for many countries. In addition to socioeconomic status, what goes on in a home is also associated with learner achievement. The early learning environment, experiences and nurturing of children are correlated with their level of cognitive development and school readiness (Melhuish et al., 2008). This chapter reports on the (i) home environments of learners and their (ii) early learning activities.

6.1. HOME ENVIRONMENT OF LEARNERS

The Coleman Report (Coleman et al., 1966), which focused on educational inequality in the 1960s, established a link between socioeconomic status and achievement, and concluded that SES explained more of the disparity in achievement than most other factors considered. Since then, other researchers have confirmed the strong positive links between SES and academic achievement (Byun & Kim, 2010; Thomson, 2018).

TIMSS 2019 asked learners about the assets and educational resources in their homes. This allows us to explore the relationship between learners' socioeconomic environments and their TIMSS mathematics and science achievements. In this section we report on the availability of home assets and the relationship between the South African constructed *Home Asset Scale*, and mathematics and science achievement, as well as the availability of home learning resources and the international *Home Resources for Learning Scale*, and its relationship with achievement. We end the section reporting on the extent to which parents were able to support learners' homework because they understood the language of the homework and the complexity of the subject matter.

Availability of home assets

The academic experiences of learners from varying socioeconomic backgrounds differ considerably, with learners whose parents have finished more years of schooling and have more financial resources performing better academically, and consequently benefitting from a variety of educational advantages (Berkowitz, Moore, Astor & Benbenishty, 2017). Figure 28 reports the percentage of learners who had what we categorised as basic, educational or digital assets in their home in 2018. 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[18].

We expected 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, 84 percent of South African households had access to electricity in 2018, but only two-thirds of homes had access to running tap water and water flush toilets, while 44 percent had access to hot water from a geyser[19].

There were statistically significant differences in the availability of these basic assets in the homes of learners attending less-affluent (no-fee) and more affluent (fee-paying or independent) schools (see Reader's Guide), clearly illustrating the inequality in the availability of resources are related to achievement. In no-fee schools, 40 percent of learners still lacked running tap water and half the learners (47%) did not have flush toilets in their homes. In comparison, a quarter of learners in fee-paying schools reported there was no running tap water and 10 percent of learners did not have flush toilets in their homes. These unequal home conditions predict the future unequal educational activities and trajectories for learners.

18 In this chapter we report the results for independent schools separately with the proviso to interpret the results cautiously as the small sample leads to high standard errors.

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

Due to the high levels of poverty (StatsSA, 2015), government provides social grants to homes in economic distress. Nationally, 60 percent of parents reported receiving a Child Support Grant (CSG). As expected, a higher proportion (70%) of children in no-fee schools were beneficiaries of the CSG. Four in ten learners in fee-paying schools and three in ten learners in independent schools were also beneficiaries of the CSG, pointing to socioeconomic disparities between learners in both no-fee and fee-paying schools.

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. Three in ten learners (29%) reported that at least one parent had a post-secondary education[20]. When disaggregated by different school types, 69 percent of learners in independent schools, 44 percent in public fee-paying schools and 21 percent in no-fee schools lived in a home where at least one parent had a post-secondary education. Learners who always spoke the language of the test at home would have had better linguistic access to the test and be able to respond to the TIMSS assessments more successfully. Nationally, one third of learners (35%) reported that they 'always or almost always' spoke the language of the test at home. The pattern differed by school type, with half the learners (50%) in fee-paying and independent schools, compared to a quarter (28%) of learners in no-fee schools, reporting that they 'always or almost always' spoke the language of the test at home.

While the availability of educational resources in the home was low for most learners, the absence of these assets was much higher for learners in no-fee schools. Lacking these resources can negatively affect learning outcomes. There was a statistically significant difference in the availability of educational resources for learners in no-fee schools compared with learners in public fee-paying or independent schools.

In an era where digital learning is becoming more important, computers or tablets and internet connectivity at home have become essential items for learning. Just over half (56%) of Grade 5 South African learners reported that they had the necessary digital hardware and 37 percent had an internet connection at home[21]. Learners in no-fee schools had less access to these resources, with only 29 percent reporting that they had an internet connection and 49 percent having a computer or tablet. The picture is different in fee-paying and independent schools, with three-quarters of learners reporting access to a computer or tablet at home and half the learners having access to an internet connection. Two-thirds of learners reported having their own cell phones, which could be considered an asset for schools to connect with learners.

20 There was 28 percent of missing values on this variable in the TIMSS 2019 dataset.

21 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 only 23 percent of households had a computer and only 9 percent had access to the internet at home (StatsSA, 2020a).

Figure 28: Percentage of learners having basic, educational, and digital assets at home, by school type

Asset type	Possession	National	No-fee paying	Fee-paying	Independent
Basic	Electricity*	84	79	95	89
	Running tap water*	66	60	79	74
	Water-flush toilets*	65	53	91	90
	Hot running water from a geyser*	44	34	67	66
	Child Support Grant*	60	70	37	29
Educational	Always/almost always speak test lang. at home*	35	28	50	49
	Parents have post-secondary education*	29	21	44	69
	Over 25 books in home*	17	12	30	36
Digital	Own cell phone*	67	62	78	73
	Computer or tablet*	56	49	72	75
	Internet connection*	37	29	56	51

* Statistically significant difference between the no-fee and fee-paying/independent groups.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

Relationship between home assets and achievement

We used the principal component analysis methodology, through the software Statistical Package for Social Sciences, to create the *Home Asset Scale*[22]. Cut-scores divided the scale scores into three categories: 1) *high* (had at least four assets, including an internet connection at home), 2) *medium* (at least four assets but no internet connection, or any three assets), and 3) *low* (less than three assets). This *Home Asset Scale* was used as a proxy for the socioeconomic status (SES) of the learner.

According to the *Home Asset Scale*, 21 percent of South African households were categorised as 'high' SES, 28 percent as 'medium' SES, and 51 percent as' low' SES. This indicator corroborated 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 4 percent elite.

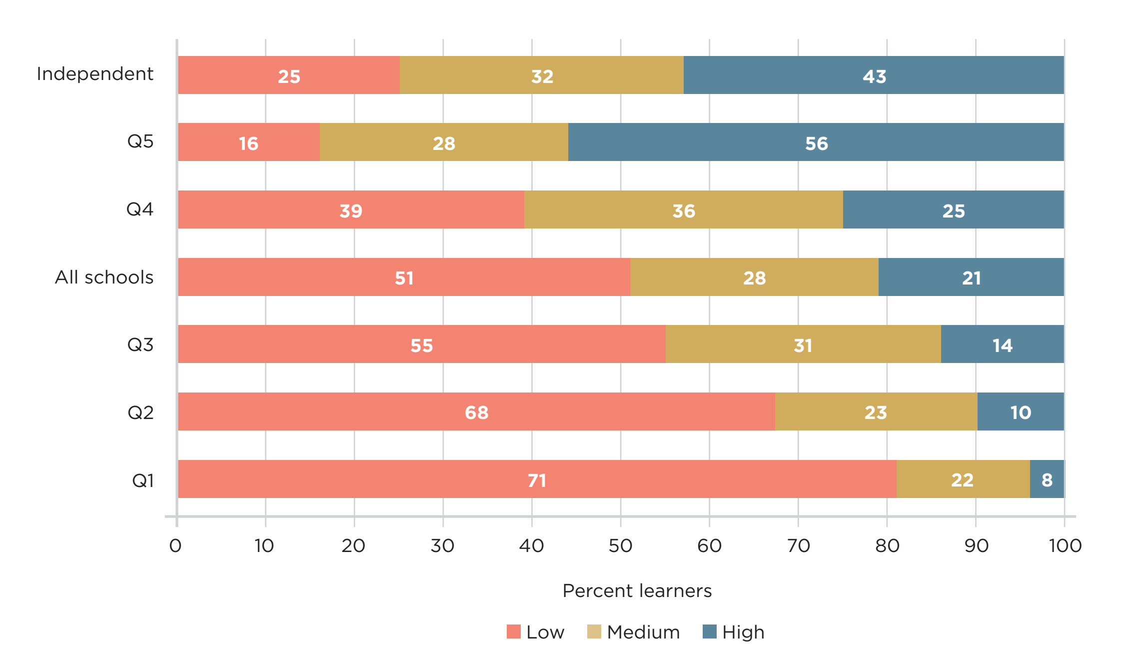
22 The scale was based on the availability of the following assets (i) Running tap water, (ii) Flush toilet in the home, (iii) Hot running water, (iv) More than 25 books in the home, and (v) Internet connection in the home.

Profile of schools by learner socioeconomic status

It is well-known that learners from higher socioeconomic backgrounds attend educational institutions with more resources and better teaching and learning conditions. In order to form a picture of the distribution of learners by SES across schools, we plotted the graph shown in Figure 29.

Close to 70 percent of learners in Quintile 1 and 2 schools and just over half the learners (55%) in Quintile 3 schools came from low SES homes. A quarter of learners in Quintile 4 schools were from high SES homes and the others were split almost equally between low and medium SES homes. Just over half the learners (56%) in Quintile 5 schools and 43 percent of learners in independent schools were from high SES homes, while 16 percent of Quintile 5 learners and a quarter of independent school learners came from low SES homes. Learners in independent schools were more socioeconomically diverse than learners in Quintile 5 schools. This graph illustrates how the reproduction of society continues, where the inequalities that began at home continued to schools having less than optimal teaching and learning conditions.

Figure 29: Percentage of learners by home socioeconomic status in school quintiles



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

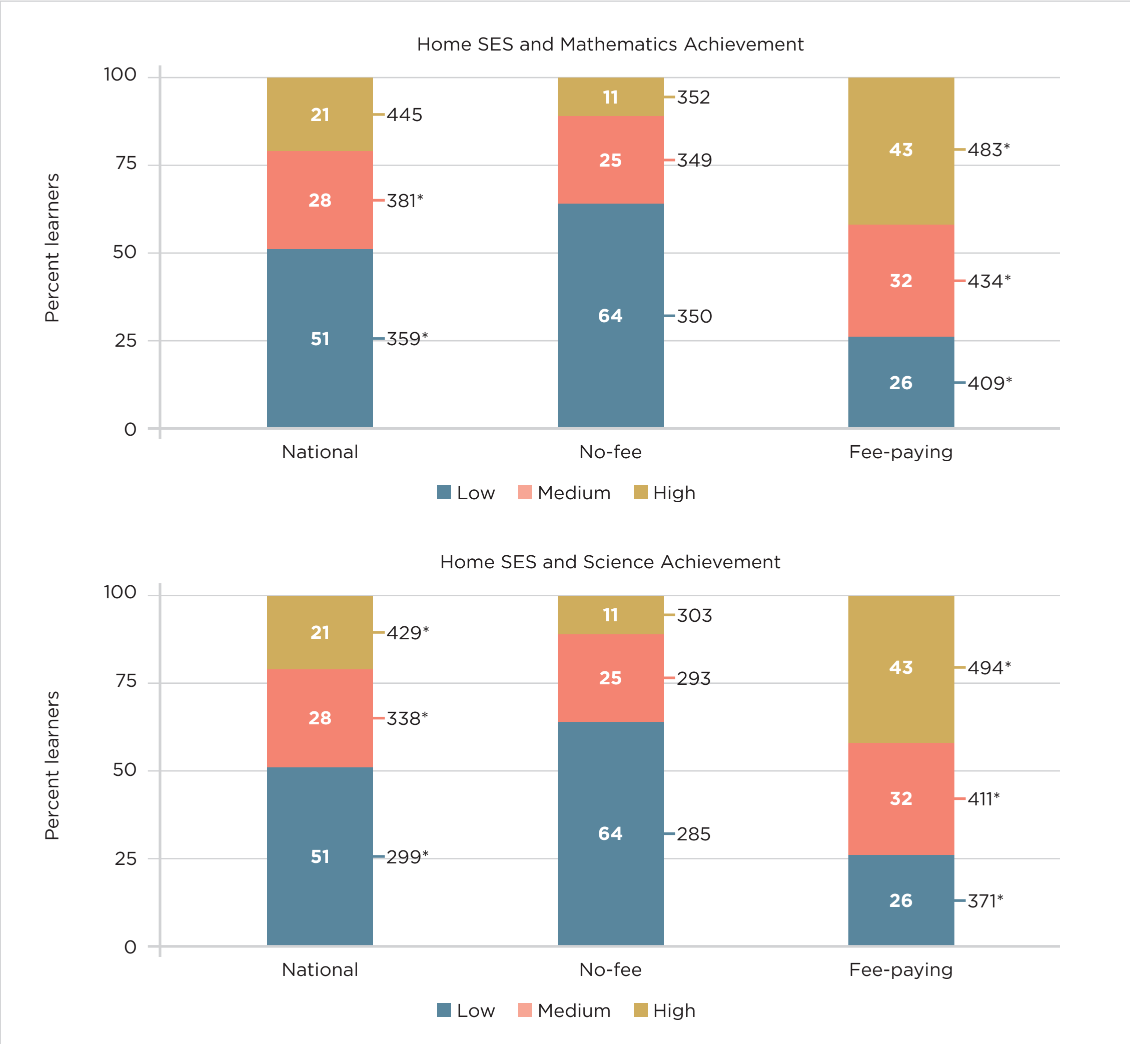
Relationship between home assets and mathematics and science achievement

We then combined school quintiles into categories of no-fee and fee-paying schools (see Reader's Guide) and examined the relationship between the *Home Asset Scale*, and mathematics and science achievement. Figure 30 presents the profile of learners by home socioeconomic status, nationally as well as in no-fee and fee-paying schools. As expected, both mathematics and science achievement had a positive relationship with the availability of home assets. Achievement was highest for Grade 5 learners from homes with the most assets (score of 445 for mathematics and 429 for science), and lowest for those learners from homes with the least assets (359 for mathematics and 299 for science).

In no-fee schools, 11 percent of learners were classified as coming from 'high' SES homes, 25 percent as 'medium' SES, and 64 percent as 'low' SES. The corresponding figures in fee-paying schools were 43 percent (high), 32 percent (medium) and 26 percent (low).

At the national level and in 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 positive relationship between mathematics and science achievement, and assets available in the home. However, we did not observe the same significant relationship for learners in no-fee schools, possibly due to learners over-reporting the availability of assets, or very low variance in achievement scores. These results confirm one of the most enduring findings in the social sciences literature: that the circumstances you were born into is the biggest predictor of where you end up.

Figure 30: Mathematics and Science achievement by socioeconomic status of the home, by school fee-status



* Statistically significant achievement differences between categories.

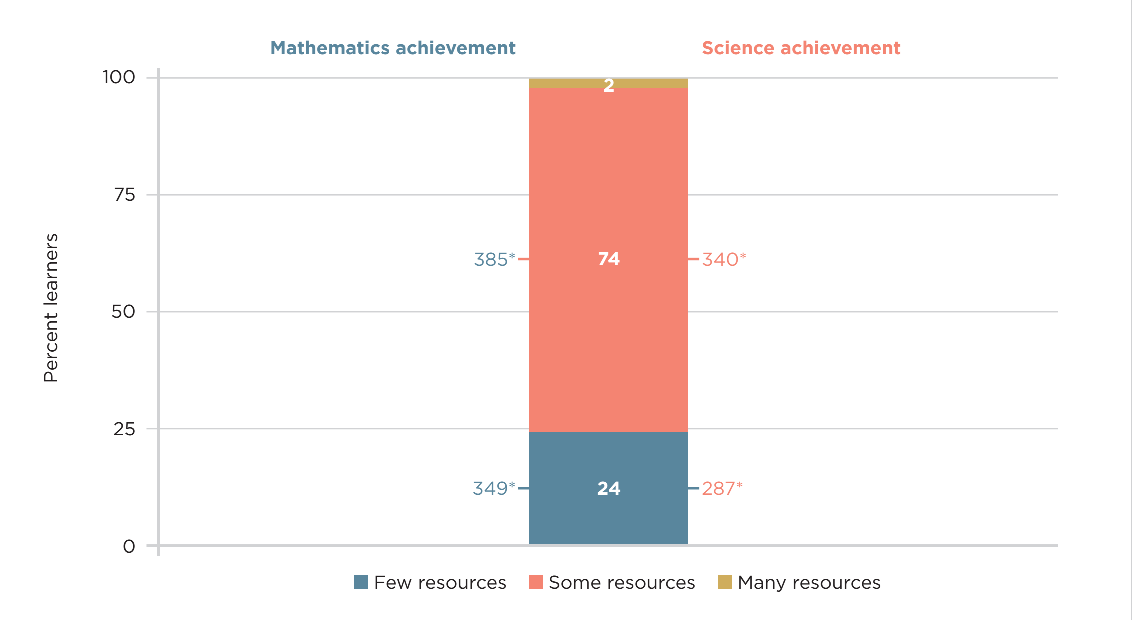
Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Home resources for learning, and mathematics and science achievement

In addition to the availability of home assets, we explored the relationship between home resources for learning and achievement. TIMSS constructed a *Home Resources for Learning Scale* from learner and parent reports[23]. Figure 31 reports the percentage of learners with different levels of home educational resources and the corresponding mathematics and science achievement.

According to the *Home Resources for Learning Scale*, only two percent of Grade 5 South African learners had 'many' home resources for learning (compared to 17 percent internationally) This group was too small to estimate its achievement mean. As with the *Home Assets Scale*, there was a significant positive association between the availability of home resources for learning and achievement. Learners from homes with 'some' resources for learning achieved significantly higher scores than those from homes with 'few' resources (385 versus 349 for mathematics, and 340 versus 287 for science).

Figure 31: Home resources for learning and achievement



* Statistically significant achievement difference between categories.

Source: TIMSS 2019 international results report.

23 The *Home Resources for Learning Scale* summarises the availability of (i) books in the home, (ii) number of children's books in the home, (iii) home study supports (own room and internet connectivity), (iv) highest level of education of either parent and (v) highest level of occupation of either parent. See Mullis et al. (2020) for a description of the *Home Resource for Learning Scale* (Exhibit 5.1).

Home support for learning

Parents expressing interest in school-related activities such as homework shows children that education and learning is important. Demographic factors like parental education have been found to positively impact the level and nature of parental involvement (Erdener & Knoeppel, 2018) in the education of learners.

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 had set aside time for homework (83%) and that their homework was completed (84%).

Barriers to providing support for learning

The ability of parents to help with homework can, however, be limited by their education levels (only 29 percent of learners had at least one parent with a post-secondary education), not speaking the language of the test, and the complex nature of the subject matter. TIMSS 2019 asked parents to indicate the extent to which they struggled with their children's homework either because of (i) the language in which the homework was provided or (ii) the difficulty level of the homework content (Table 13 and Table 14).

Half the parents reported that they 'hardly ever' struggled with the language of the homework and 43 percent reported that they hardly ever struggled with the content of the homework. Learners whose parents reported that they 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 sometimes or frequently struggled. These findings reinforce the findings in the literature that having more home educational capital is associated with higher achievement scores.

Table 13: Relationship between parents supporting learners' homework and mathematics achievement

	Hardly Ever		Sometimes		Often	
	Percent learners	Math Scores (SE)	Percent learners	Math Scores (SE)	Percent learners	Math Scores (SE)
Parents struggle with language of homework	49	407* (4.0)	39	349* (3.6)	12	340* (4.4)
Parents struggle with content of homework	43	401* (4.4)	46	364* (3.7)	11	334* (4.1)

* Statistically different achievement scores between groups.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset. .

Table 14: Relationship between parents supporting learners' homework and science achievement

	Hardly Ever		Sometimes		Often	
	Percent learners	Science Scores (SE)	Percent learners	Science Scores (SE)	Percent learners	Science Scores (SE)
Parents struggle with language of homework	49	371* (5.6)	39	287* (4.7)	12	273* (5.0)
Parents struggle with content of homework	43	361* (6.1)	46	310* (4.7)	11	268* (5.7)

* Statistically different achievement scores between groups.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

6.2. EARLY LEARNING ACTIVITIES

A considerable body of research, including the previous TIMSS 2015 Grade 5 study (Isdale et al., 2017), documents the importance of early childhood learning activities in laying the groundwork for subsequent achievement during the school years. These educational activities help promote early cognitive, linguistic and motor skills, and contribute to children's levels of school readiness. In addition to what parents have and what they do with their children, the level of cognitive stimulation they provide through engaging them in early educational activities and the pre-school settings they access, are important characteristics of the home environment. These characteristics are significantly, and independently, associated with the development of literacy and numeracy skills.

This section explores the early educational environment and its relationship with Grade 5 learners' mathematics and science scores based on parents' or guardians' responses. We present results for South Africa, public no-fee and fee-paying schools as well as for, where possible, independent schools.

Early Learning Activities

In the Home Questionnaire parents were asked, "Before your child began school, how often did you (or someone else at home) do the following with him or her?" In total, parents were asked about 18 different types of activities and responded on a scale of 'often', 'sometimes', or 'never or almost never'.

Frequency of engaging in selected early educational activities

Figure 32 shows the proportion of learners whose parents reported 'often' engaging their children in a number of different literacy and numeracy focused activities before they started school.

Across the early educational activities considered, just over a third of learners experienced frequent engagement with most activities, while drawing shapes (52%) and playing with number toys (41%) were the most reported. There was variation by school type, with learners in fee-paying and independent schools experiencing more cognitively stimulating early home environments than those who went on to attend no-fee schools. Compared with the international average reported for TIMSS 2019 (Mullis et al., 2020), South African learners typically experienced lower levels of cognitive stimulation at home in the years before formal schooling started.

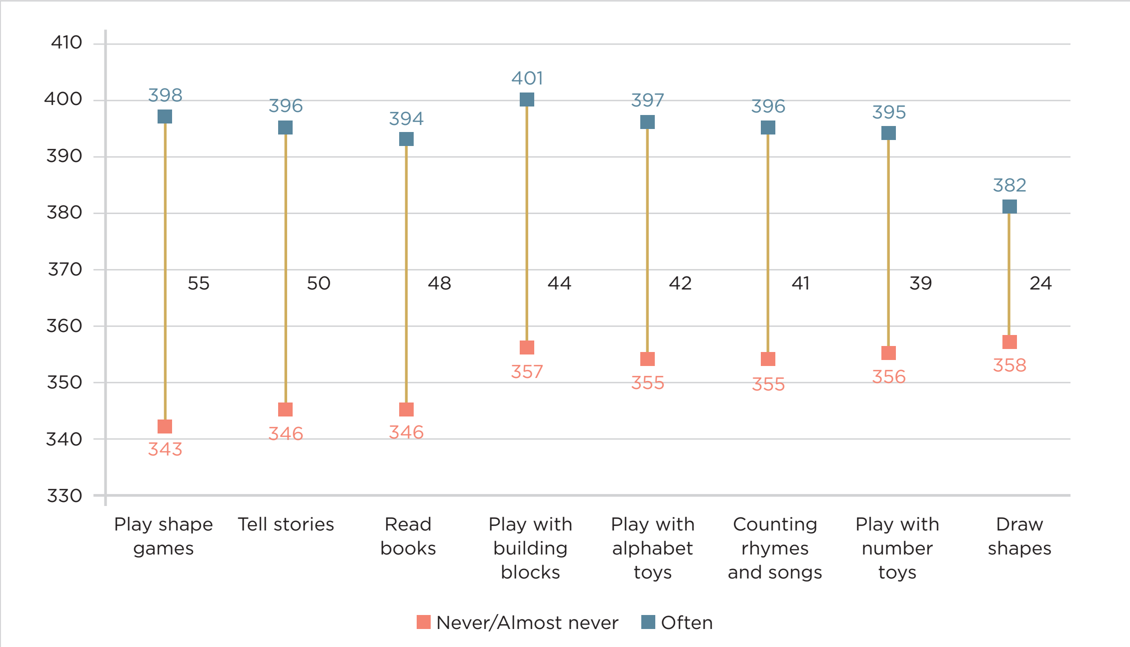
Figure 32: Percentage of learners whose parents reported often engaging in selected early educational activities

	Literacy-related activities			Numeracy-related activities				
	Read books	Tell stories	Play with alphabet toys	Counting rhymes and songs	Play with number toys	Play shape games	Play with building blocks	Draw shapes
South African average	35	34	34	37	35	41	34	52
TIMSS international average	50	50	45	41	43	57	62	49
No-fee	34	31	30	33	33	37	29	50
Fee-paying	37	41	43	45	41	50	45	55
Independent	45	45	46	43	46	57	48	53

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

The early educational activities reported in Figure 32 were all positively associated with higher achievement in both mathematics and science. These achievement differences between 'often' and 'never or almost never' engaging in early learning activities were not small. The smallest difference between regular engagement and no engagement was for drawing shapes (24 points in mathematics achievement and 33 points in science). Learners whose parents reported often playing shape games with their children before they started school scored, on average, 55 points higher in the mathematics assessment and 76 points higher in the TIMSS science assessment than those who never or almost never did (see Figure 33 and Figure 34). All differences reported were statistically significant.

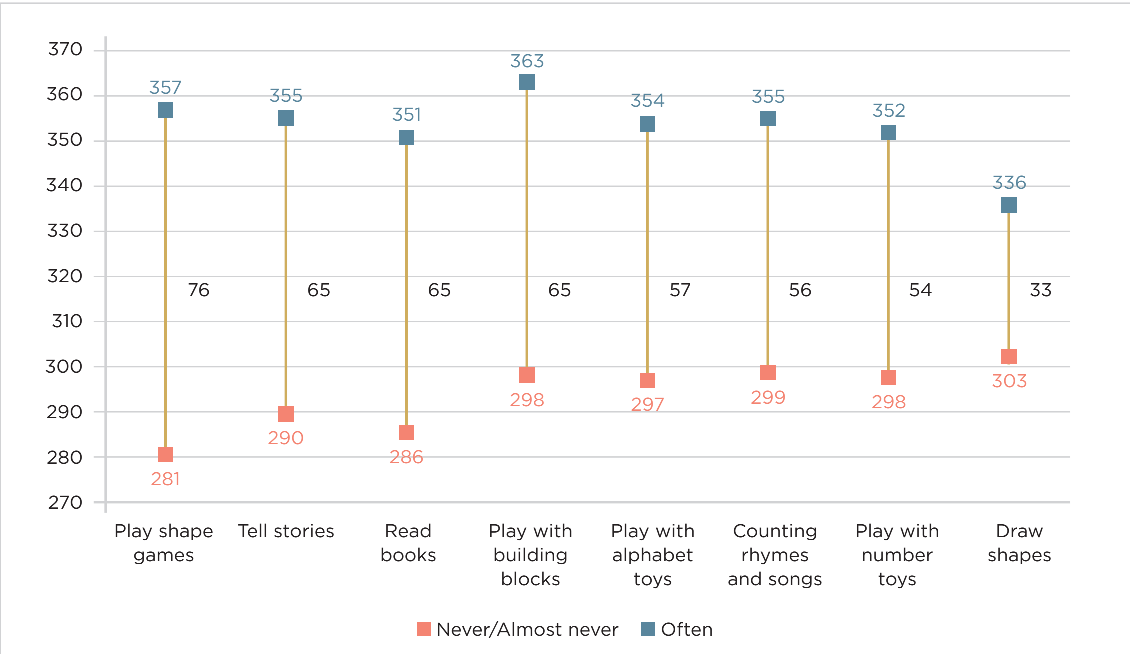
Figure 33: Mathematics achievement, and achievement difference, by frequency of engaging in early learning activities



All achievement differences between Often and Never or Almost Never were statistically significant.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

Figure 34: Science achievement, and achievement difference, by frequency of engaging in early learning activities



All achievement differences between Often and Never or Almost Never were statistically significant.

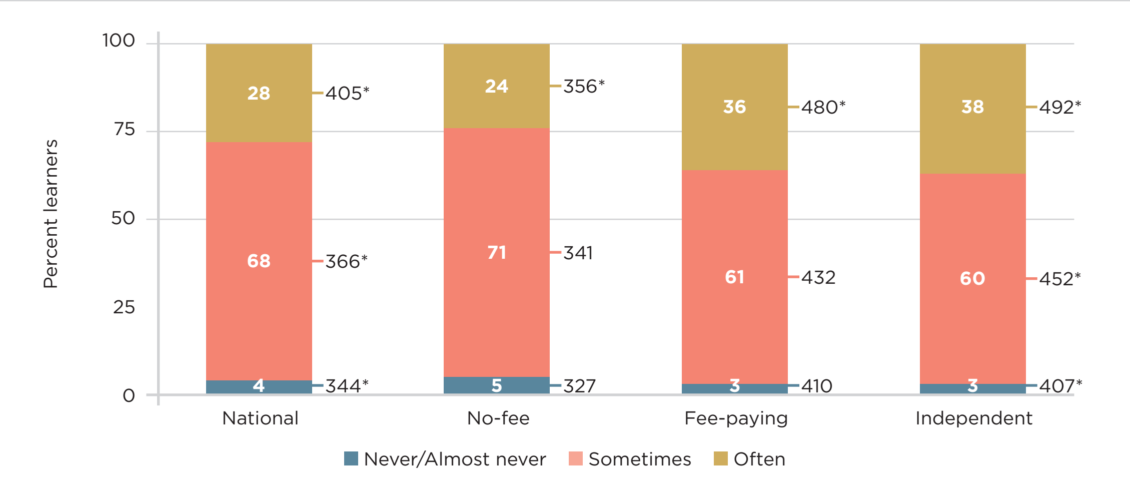
Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

Early learning activities scale and achievement

Learners were scored according to their parents' reports regarding the frequency with which they engaged their children in 18 activities to create an *Early Literacy and Numeracy Activities Scale*. The scale was then divided into three categories: 1) *often*, 2) *sometimes* and 3) *never or almost never* engaged in these activities at home[24]. In general, parents reported a fair level of early interaction with their children, with 28 percent of learners having parents who reported 'often' engaging with them, a further 68 percent whose parents 'sometimes' engaged them and just four percent of learners had parents who reported 'never or almost never' engaging them in early literacy or numeracy activities. The corresponding international averages were 42 percent for often, 55 percent for sometimes and three percent never or almost never engaging.

Figure 35 and Figure 36 show the variation in how frequently parents engaged children in these home-based, early educational activities by school type, and the association with their Grade 5 achievement. For example, more than a third of learners in fee-paying (36%) and independent (38%) schools lived in households where parents frequently engaged them in early literacy and numeracy activities, compared to just under a quarter (24%) of those in no-fee schools. There was a positive relationship between the frequency of engaging in early educational activities and subsequent achievement.

Figure 35: Home early literacy and numeracy activities and mathematics achievement, by school type



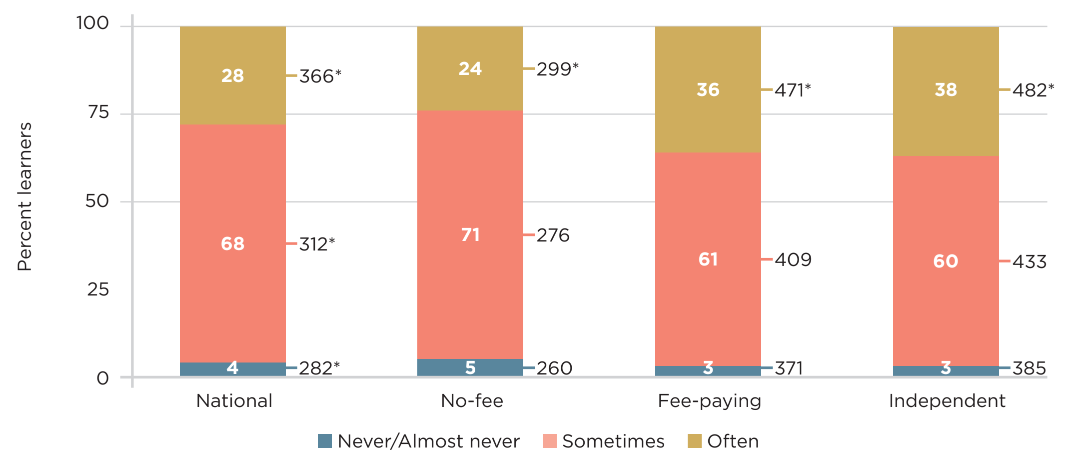
* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

In the public fee-paying schools, the difference between the two extreme categories of the engagement index was an average of 70 points (410 for never to 480 for often) for mathematics. In independent schools, the difference was 85 points, with frequent engagement in educational activities increasing average performance from 407 to 492 points. While smaller for learners in no-fee schools, the relationship between an early emphasis on literacy and numeracy development and later achievement was also positive and significant. Learners in the most cognitively stimulating environments achieved an average of 29 more points in mathematics than those learners in environments where early educational activities were largely absent (327 compared to 356 points).

24 See Mullis et al. (2020) Exhibit 5.11 for further detail about the scale.

Figure 36: Home early literacy and numeracy activities and science achievement, by school type



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

For science, despite lower average overall achievement, the gains for learners in the most stimulating home environments were greater than in mathematics. For learners in fee-paying schools, the average difference in the TIMSS science score from a household where parents never or almost never engaged in early literacy and numeracy activities to one where they frequently did was 100 points (371 versus 471). Similarly, in independent schools this difference was, on average, 97 points. Of particular interest was the difference for learners in no-fee schools, where moving from a low to a high level of cognitive stimulation in the home was, on average, 39 points and statistically significant.

Early learning activities and parental level of education

As we showed earlier (Table 13 and 14), learners from more educated households scored higher in both the mathematics and science assessments, as did those experiencing more cognitively enriched early environments (Figure 33 and 34). Table 15 shows the relationship between engagement in early literacy and numeracy activities and parents' own level of education, highlighting the ways in which different learner contexts interact.

For mathematics achievement, the average difference between 'never or almost never' and 'often' engaging in early literacy and numeracy activities at home for learners in households with low levels of education (below Grade 12) was 22 points. Most strikingly, the achievement difference between learners from households with low levels of education and where early educational engagement was absent, compared to those from educationally rich environments (where one or both parents had a post-secondary qualification and often engaged in literacy and numeracy activities) was close to 150 points (i.e. 472 – 328).

Table 15: Home early literacy and numeracy activities, household education and mathematics achievement

			Highest Household Educational Level		
			Below Grade 12	Completed Grade 12	Post-secondary
		Percent learners	30	42	29
Frequency of activities	Percent learners	Average Achievement (SE)	340 (1.5)	371 (1.5)	436 (2.2)
Never /Almost never	4	344 (4.4)	328 (6.0)	349 (8.1)	393 (13.7)
Sometimes	68	366 (1.1)	340 (1.8)	366 (1.7)	419 (2.7)
Often	28	405 (1.9)	350 (3.5)	390 (2.9)	472 (3.5)

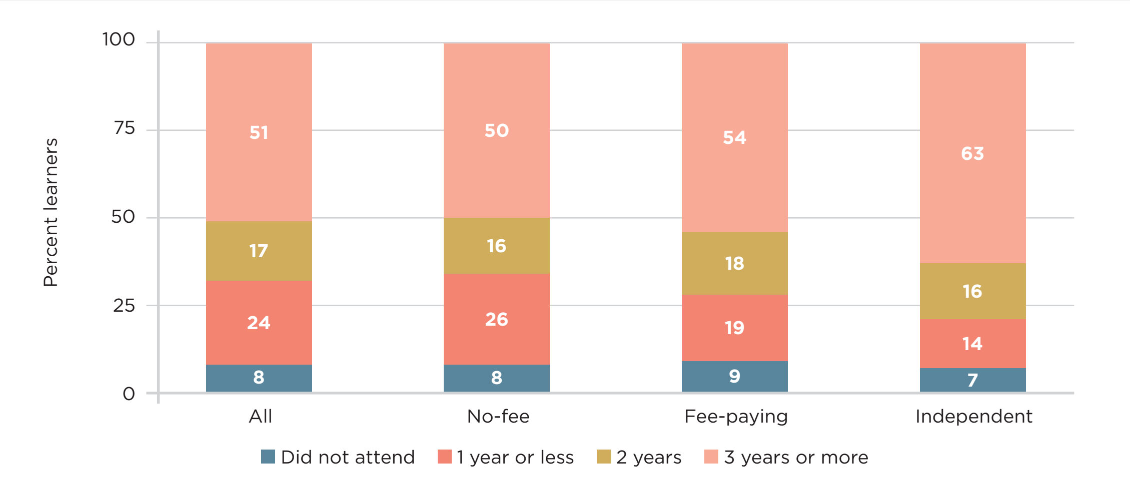
Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

All achievement differences were statistically significant with the exception of the difference between the scores of learners in the cells Below Grade 12 household and Completed Grade 12 households where the Frequency of Activities is Never/Almost never.

Preschool attendance

Most Grade 5 South African children (92%) attended pre-schools and thus had some form of early education. Learners who went on to attend fee-paying or independent schools spent longer, on average, in preschool settings: half the learners in no-fee schools (50%) spent three years or more in a preschool setting compared to 54 percent of those in fee-paying schools and 63 percent of those who attended independent schools (Figure 37).

Figure 37: Percentage of learners that attended preschool, by school type



Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

In general, there was a positive association between the number of years spent in preschool and subsequent achievement in mathematics and science, both in South Africa and internationally. Internationally, learners who attended pre-primary school for three years or more achieved the highest average mathematics and science scores in Grade 5. Those with less pre-primary school attendance had successively lower average science and mathematics achievement scores.

Table 16 shows the pattern for South African learners: learners who spent one year or less in preschool scored slightly lower in the Grade 5 assessment than those who did not attend any form of preschool setting. However, this difference was not statistically significant. For both mathematics and science, the difference in TIMSS achievement was statistically significant when moving from one year or less of pre-school attendance to two years. Other year-on-year differences were not statistically significant.

Table 16: Achievement in TIMSS at Grade 5, by preschool attendance

	South Africa					International average				
	Percent learners	Mathematics (SE)		Science (SE)		Percent learners	Mathematics (SE)		Science (SE)	
Did Not Attend	8	368	(6.7)	313	(10.1)	12	464	(1.4)	452	(1.5)
1 Year or Less	24	359*	(3.8)	304*	(5.3)	15	483	(1.0)	472	(1.0)
2 Years	17	383*	(4.7)	339*	(6.6)	17	495	(1.0)	489	(1.1)
3 Years or More	51	388	(5.1)	343	(6.9)	56	509	(0.6)	500	(0.7)
South African Average		**374**	**(3.6)**	**324**	**(4.9)**					

* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 early learning and learner background dataset and Mullis et al. (2020).

Grade R attendance

Most South African learners attended Grade R, with less than one in ten children missing out. As with preschool attendance, slightly more learners in fee-paying and independent schools attended Grade R, than those in no-fee schools. Most learners attended a Grade R class linked to a primary school in no-fee (80%), fee-paying (69%) and independent (78%) schools, with the remainder attending a centre not linked to a primary school.

As with pre-school attendance, there was a positive, and significant, relationship between whether or not learners attended Grade R and their subsequent Grade 5 achievement. Learners who attended Grade R significantly outperformed their peers in mathematics (378 versus 343 points) and science (329 versus 282 points) in the TIMSS Grade 5 assessments (Table 17 and Table 18). This relationship was also significant for public no-fee and fee-paying schools.

Table 17: Percentage of learners who attended Grade R, by school type, and mathematics achievement

	All		No-fee		Fee-paying		Independent	
	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)
No	8	343* (4.7)	9	329* (3.4)	7	385* (10.4)	5	424 (36.9)
Yes	92	378 (3.6)	91	345 (5.1)	93	454 (7.0)	95	467 (15.3)

* Statistically significant achievement difference between learners who attended Grade R and those who did not.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

Table 18: Percentage of learners who attended Grade R, by school type, and science achievement

	All		No-fee		Fee-paying		Independent	
	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)	Percent learners	Achievement (SE)
No	8	282* (6.3)	9	260* (6.4)	7	348* (14.1)	5	405 (49.1)
Yes	92	329 (4.8)	91	282 (4.7)	93	437 (9.1)	95	451 (20.3)

* Statistically significant achievement difference between learners who attended Grade R and those who did not.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

Early academic skills

Children who arrive at school ready to learn, with the requisite skills in place, fare better in terms of later achievement. Parents were asked to rate their children's readiness for school in terms of both literacy and numeracy development at the start of Grade 1. We explored the extent of early literacy and numeracy skills of children and the relationship with achievement.

Early literacy and numeracy skills

According to parents' reports (Table 19), over half (52%) of all learners were able to recognise most of the letters of the alphabet 'very well' at the start of Grade 1, with almost four in ten (38%) learners able to read some words and half (49%) able to write letters very well. These are comparable with the TIMSS international averages. Three quarters of learners' parents reported that they could write their name very well on beginning Grade 1, which was eight percentage points higher than the international average.

Fewer South African learners were rated as having strong numeracy skills. Around a quarter of parents reported learners as having strong numeracy skills, on the three measures, when starting Grade 1. This was lower than the international average.

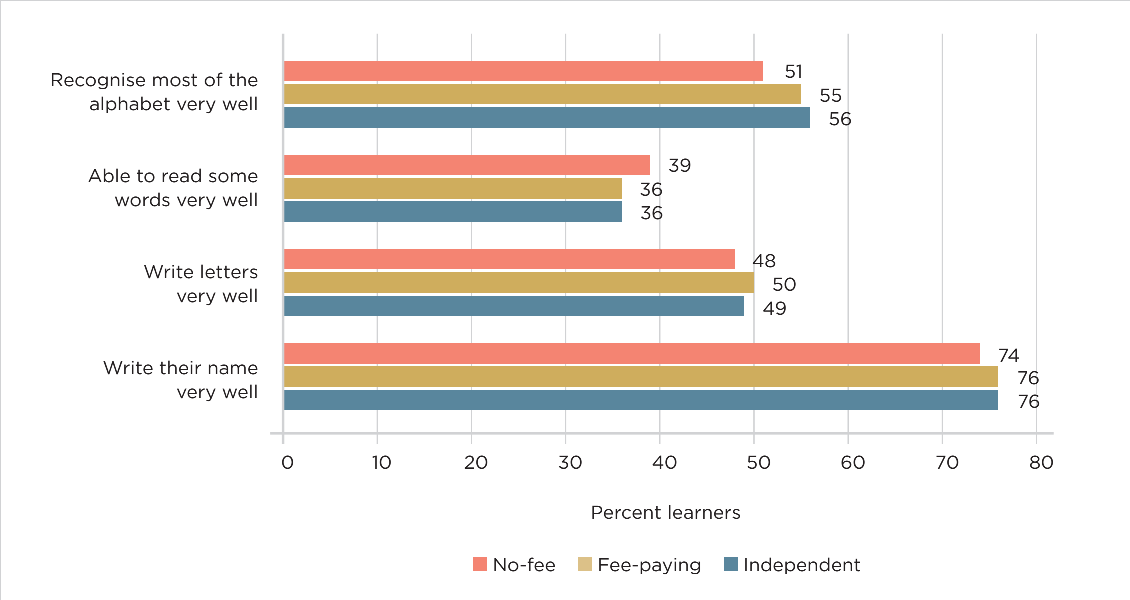
Table 19: Percentage of learners with strong literacy and numeracy skills when starting Grade 1

		Percent learners South Africa	Percent learners International
Literacy	Recognise most of the alphabet very well	52	53
	Able to read some words very well	38	35
	Write letters very well	49	45
	Write their name very well	75	67
Numeracy	Counting on own up to 100 or higher	28	36
	Recognise written numbers up to 100 or higher	24	30
	Write numbers up to 100 or higher	27	28

Source: TIMSS 2019 Grade 5 dataset and Mullis et al. (2020).

Comparing learners' literacy skills by school type suggests that those in fee-paying and independent schools fared slightly better than those in no-fee schools (Figure 38), but the differences were not significant.

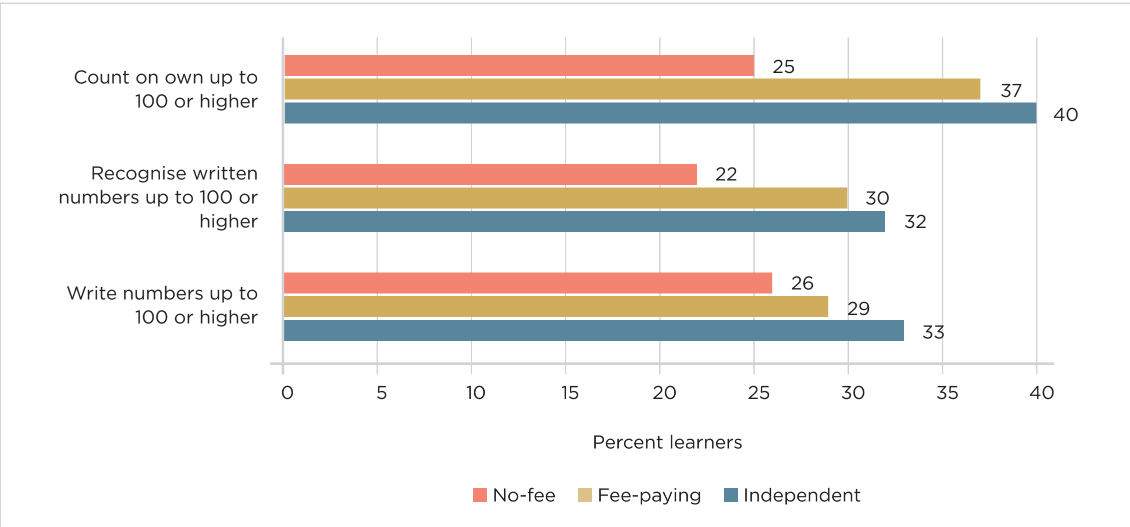
Figure 38: Percentage of learners with strong literacy skills prior to Grade 1, by school type



Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

The differences in learners' numerical readiness between school type were more pronounced than for early literacy skills (Figure 39). Learners' numeracy readiness in independent schools was rated significantly higher than learners in no-fee schools.

Figure 39: Percentage of learners with strong numeracy skills prior to Grade 1, by school type

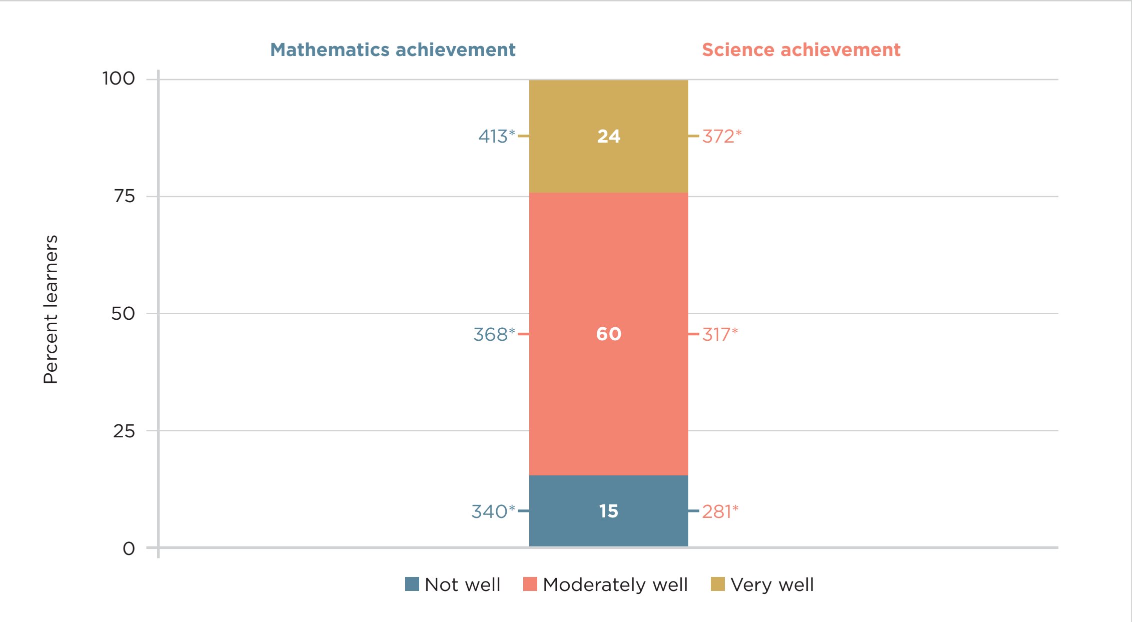


Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

Academic skills prior to Grade 1 and later achievement

Learners were scored according to parents' reports regarding how well their children performed on the 12 tasks on the *Early Literacy and Numeracy Scale*[25] when they began primary school. Cut-scores divided the scale into three categories: 1) *Very Well*, 2) *Moderately Well* and 3) *Not Well*. On this scale 24 percent of South African learners were rated as being able to do literacy and numeracy tasks 'very well' at the start of Grade 1 (Figure 40). The international average was 25 percent and the South African rating was higher than many higher performing countries[26] (Russian Federation at 24 percent, France 14 percent, Norway 10 percent and Germany 7 percent). Although the South African rating of learners' early literacy abilities seems high, we still observed a strong positive, and statistically significant, association between reported learner academic skills at the beginning of Grade 1 and their performance in Grade 5 mathematics and science. Learners who were reported as having a better foundation in literacy and numeracy skills upon entering Grade 1 outperformed those with lower skills in these areas by an average of 73 points in mathematics and 92 points in science.

Figure 40: Early literacy and numeracy abilities and Grade 5 achievement



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 Grade 5 datasets.

In the following infographic we summarise aspects of the home environments within which learners lived, their early learning preparation and the relationship with their Grade 5 mathematics and science achievement.

25 See Mullis et al. (2020) Exhibit 5.18.

26 There may have been a reporting bias, with parents over-estimating the skill sets of their children.

6.3. SUMMARY: LEARNERS' HOME ENVIRONMENT AND EARLY LEARNING PREPARATION

Home assets and achievement

Access to basic amenities has been shown to facilitate learners' successful participation in learning. However, only two-thirds of homes had access to running tap water and water flush toilets, and only 44 percent had hot water from a geyser. Learners in no-fee schools had less access to these basic amenities than their counterparts in public fee-paying and independent schools. There was also a high level of economic distress in households, with 60 percent of parents reporting receiving the Child Support Grant.

According to the *South African Home Asset Scale*, 21 percent of South African households were categorised as high SES, 28 percent as medium SES, and 51 percent as low SES. Most learners in Quintile 1, 2 and 3 schools came from low SES households.

There was a significant positive relationship between mathematics and science achievement and assets, as well as educational resources, 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 a predictor of where you end up.

Home support for learning mathematics and science

Parental education is a proxy of the wealth and social capital of the household and has strong positive links with learner achievement. Half the parents reported that they could support learners with their homework. Learners whose parents did not struggle with the language or complexity of the homework achieved higher mathematics and science scores than those whose parents struggled.

Early learning activities and achievement

More than a third of learners in fee-paying and independent schools lived in households where parents often engaged them in early literacy and numeracy activities, compared to just under a quarter of those in no-fee schools. Higher levels of engagement in educational activities in the home were positively and significantly linked to academic achievement in all three school types.

Learners from more educated households experiencing more cognitively enriched early environments scored higher in both the mathematics and science assessments, than learners from households with less education and less cognitively enriched early environments.

Preschool and Grade R attendance

Ninety two percent of learners attended preschool, including Grade R. Half the learners attended for three years or more, 17 percent for up to two years, and 24 percent for one year or less. The TIMSS achievement were significantly higher when moving from one year or less of preschool attendance to two years. Learners who attended Grade R achieved significantly higher mathematics and science scores than those who did not attend Grade R.

Early academic skills

Children who arrive at school with the requisite literacy and numeracy skills in place fare better in terms of later achievement. Around half the learners were rated as having strong literacy skills, compared with a quarter of the learners having good numeracy skills prior to entering Grade 1.

Chapter 7 examines factors within schools that facilitate the provision of enabling learning environments, and how these factors are related to learners' achievement.

SECTION E

SCHOOL AND CLASSROOM FACTORS RELATED TO ACHIEVEMENT

In addition to collecting achievement data, a School Questionnaire was administered to the principal of each participating school, and the mathematics and science educator of each class that took part in the TIMSS assessment was asked to complete an Educator Questionnaire. 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 all results by learner outcomes. The principal, and mathematics and science educator responses represent the educator and school characteristics that a typical learner would face. Therefore, when information from educators and schools is 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. We acknowledge that, similar to other low-performing countries, the South African responses were more positive on some items, which does not always match the educational reality, and therefore must be treated cautiously.

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, resources in schools and classrooms, class sizes, classroom instructional practices and the use of computers for instruction.

CHAPTER SEVEN

SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

According to a number of empirical studies, children's socioeconomic status (SES) is one of the most important indicators of their future educational success (García & Weiss, 2017). When high quality education is exclusively available to wealthy households, social mobility is harmed. Performance differences between children of different social classes emerge early in life and these gaps remain evident in later years (Walker, Pearce, Boe & Lawson, 2019). Therefore, in the context of high household poverty levels, parents and society view schools and classrooms as the institutions best placed to equalise opportunities for learners from poorer homes and to level the playing field of educational success.

For schools to play the role of equaliser they must be well-functioning. Schools need to be managed by a principal with suitable skills, qualifications and strong leadership skills, and who is able to appropriately utilise the resources at their disposal. Furthermore, good working conditions, facilities and sufficient resources are important for promoting a conducive learning environment.

In this chapter we present the results for the following:

(i) The school characteristics in terms of school classification by fee-paying status, profile of schools by learners' SES, and the geo-location of schools;

(ii) The school principals' demographics, as well as their leadership and management support characteristics; and

(iii) The school climate, both by describing the emphasis placed on academic success as well as the extent to which school discipline and safety problems, safe and orderly schools and incidences of bullying, were associated with achievement.

7.1. SCHOOL CHARACTERISTICS

The schools that learners attend form part of the broader context within which they live and learn. School characteristics shape the learning environment. The South African schooling system is made up of 95 percent of learners in public schools and five percent in independent[27] schools (EMIS data, 2020). Public schools are state controlled, while independent schools are privately governed[28].

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 classification by the socioeconomic status of schools, learners' socioeconomic status in schools, and the geo-location of schools.

27 Independent schools are a diverse group ranging from schools receiving state subsidy to highly exclusive, high fee schools.

28 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 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.

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 (RSA, 1996c) 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).

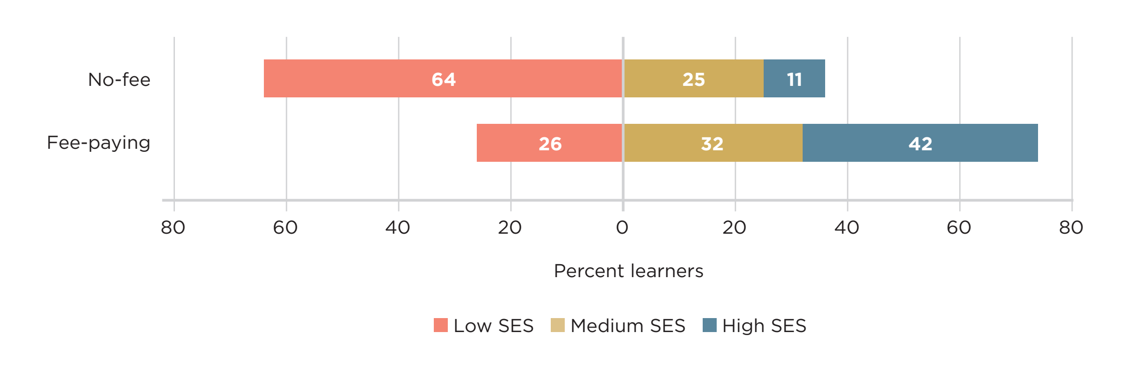
To this end, a school poverty index was created for each school. The National Norms and Standards for School Funding (RSA, 2012a: 3) aimed to improve equity in the funding of education by ranking each school into one of five quintiles. This ranking is based on the income, unemployment rate and literacy rate of the community in which the school is located. A Quintile 1 ranking indicates a more impoverished school, and a Quintile 5 ranking indicates a more 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)[29], thereby being denied access to school. Presently, learners in Quintiles 1, 2 and 3 schools make up three-quarters of public schools and are categorised as no-fee schools.

Profile of schools by socioeconomic status of learners

Since the Coleman report (Coleman et al., 1966), there has been great awareness on how the socioeconomic composition of learners in a school is associated with individual learner achievement. Recent literature provides further evidence of this relationship (e.g. Harwell & Zhao, 2021; Juan & Visser, 2017; Reddy et al., 2019). Gruijters and Behrman (2020) highlight three ways through which family socioeconomic status is likely to influence learning in francophone African countries: (1) home educational resources, (2) health and wellbeing, and (3) disparities in the quality of schools that learners attend. They found school quality to be particularly important and improving the quality of all schools is therefore 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 29 in Chapter Six. Overall, 21 percent of Grade 5 learners came from households categorised as high SES, 28 percent as medium SES and 51 percent as low SES. Figure 41 shows the socioeconomic profile of Grade 5 learners in no-fee and fee-paying schools (see Reader's Guide). Two-thirds (64%) of learners who attended no-fee schools had very few basic assets at home and were categorised as low SES, compared to a quarter (26%) of learners in fee-paying schools. The stark differences in the SES of households indicate that learners enter the education system with different levels of school readiness, support and resources; and learners in no-fee schools depend more on school inputs to raise their education levels.

Figure 41: Profile of South African schools by socioeconomic status of learners



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

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

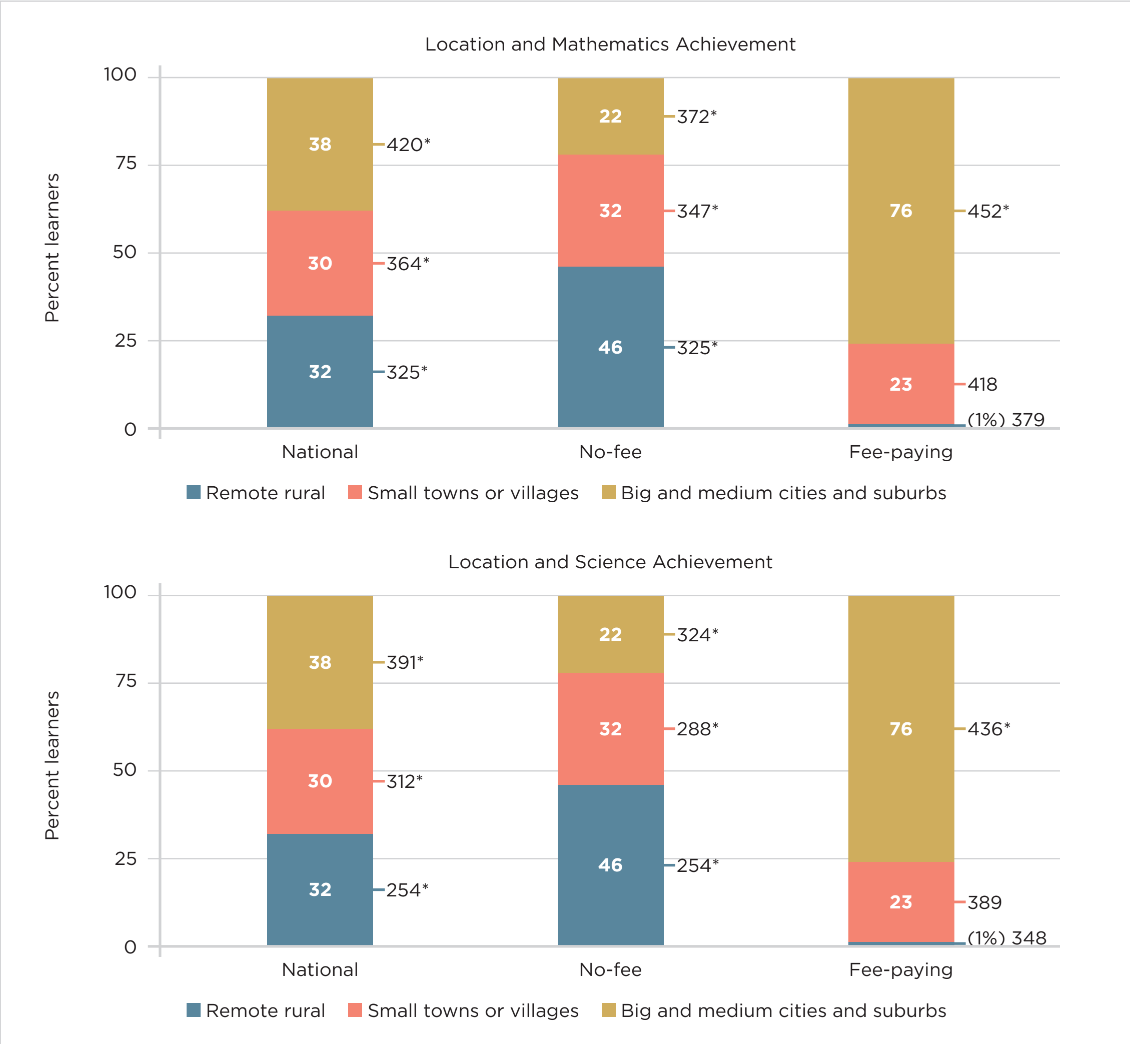
Profile of schools by their geo-location

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. Research has shown strong correlations between academic achievement and the location of the school that learners attend (Babawale, Olayinka & Teacher, 2019). There are almost twice as many children living in rural areas, facing multidimensional poverty (i.e. the experience of multiple deprivations simultaneously) compared to their urban counterparts (StatsSA, 2020b).

Nationally, close to a third of Grade 5 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 was different for no-fee and fee-paying schools: three quarters of learners in fee-paying schools attended schools located in big and medium cities and suburbs, compared to 22 percent of no-fee learners. Just under half of the learners in no-fee schools attended schools in remote rural areas.

We explored the relationship between where the school was located, and the mathematics and science achievement of learners attending the school (Figure 42). Nationally, learners attending schools in big and medium-size cities and suburbs attained significantly higher mathematics and science achievement scores than those attending schools in remote rural areas (420 versus 325 for mathematics, and 391 versus 254 for science). This relationship was robust at the national level, as well as in no-fee and fee-paying schools.

Figure 42: Learners attending schools by geo-location and achievement, by school fee-status



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

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 principals' qualifications and experience, as well as their leadership and management styles, and educational achievement (Osborne-Lampkin, Folsom & Herrington, 2015). In this section we 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

Three-quarters of Grade 5 learners attended schools where the principal's qualification was, at least, a Bachelor's degree, while a quarter of learners attended schools where the principal had not completed a Bachelor's degree (Table 20). The patterns were similar in both no-fee and fee-paying schools.

On average, learners attended schools where the principal had nine years of experience as a principal, with approximately a third (32%) having less than five years' experience, a third (31%) having between 5 and 10 years, and a third (37%) having more than 10 years' experience.

Table 20: Percentage of learners by principals' education level and school fee-status

Principals' education level	School fee-status		
	National	No-fee	Fee-paying
Completed post-graduate degree	11	10	12
Completed Bachelor's degree	65	67	62
Did not complete Bachelor's degree	24	23	27

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 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 attributes on seven statements and school management support on four statements. In Table 21 and Table 22, we report mathematics educators' responses[30], by the percentage of learners who attended schools where principals' leadership and management support were rated highly.

Overall, most learners attended schools where educators positively rated both the principal on their leadership attributes, and the school management on their support. Close to 80 percent of learners attended schools rated positively by educators in relation to the principal letting the teaching staff know what was expected of them and being friendly and approachable, and where the school management team protected teaching and learning time. The principals' ability to look at all angles of a problem and to consider the input of others was rated the lowest, with just over half (55%) of learners being in schools where educators strongly agreed with this statement.

Educators in no-fee schools, in comparison to fee-paying schools, rated the principal significantly higher on the items 'put suggestions made by the teaching staff into operation', 'treats all staff as his or her equal' and 'explores all sides of topics and recognise that other opinions exist'.

30 Responses for science were similar

Table 21: Percentage of learners attending schools where principals' leadership was highly rated by educators

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	80	78	84
is friendly and approachable	77	77	76
is willing to make changes	67	70	60
maintains definite standards of performance	65	64	69
puts suggestions made by the teaching staff into operation	64	68*	54
treats all staff as his or her equal	61	66*	49
explores all sides of topics and recognises that other opinions exist	55	59*	44

* Statistically significant difference between no-fee and fee-paying schools.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

Table 22: Percentage of learners attending schools where support by school management was highly rated by educators

Support by school management...	Percent learners in schools rated 'high' or 'very high'		
	National	No-fee	Fee-paying
school management commitment to protecting teaching and learning time	85	86	83
collaboration between school management and educators	73	75	69
school management's observation of teaching practices	70	70	71

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

7.3. SCHOOL CLIMATE

School climate is a multi-dimensional concept that refers to the character and quality of school life and reflects norms, values, and interpersonal connections based on patterns of school stakeholders' experiences of school life (Kostyo, Cardichon & Darling-Hammond, 2018). TIMSS measured school climate by examining a set of factors that have been demonstrated to influence how schools operate (Winnaar, Arends & Beku, 2018). In this section we report on two aspects of the TIMSS school climate framework: the emphasis schools placed on academic success; 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. York, Gibson and Rankin (2015) highlighted six aspects that define academic success, namely: "academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational outcomes, and post-college performance".

Principals rated the educator, parent and learner-related aspects of emphasising academic success in the School Questionnaire. Table 23 provides principals' ratings on given aspects 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-related 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 reported that parents had high expectations of learner achievement (50%), but that their involvement (24%), commitment (17%) and support (15%) related to school activities were low. When it came to learners, principals reported that 42 percent of learners respected academic excellence, and that only around a quarter of learners had the ability (29%) and a third the desire (34%) to do well in school.

The ratings of the role of educators, parents and learners in relation to the aspects of academic success were more positive in fee-paying than in no-fee schools, with a statistically significant difference on the following educator items: educators' understanding of curricula goals, and degree of success in implementing the school's curriculum. Parental involvement in school activities was significantly higher in fee-paying schools on the following items: commitment to ensure that learners are ready to learn, and support for learner achievement. There were significantly more learners in fee-paying schools who were rated as having the ability to reach the school's academic goals.

Table 23: Principals' responses to the aspects of school emphasis on academic success (by percentage of learners)

	Percent learners in schools where aspects were rated as 'high' or 'very high'		
	National	No-fee	Fee-paying
EDUCATORS'...			
expectations for learner achievement	82	82	81
understanding of the school's curricular goals	75	70	86*
ability to inspire learners	73	70	81
degree of success in implementing the school's curriculum	65	58	80*
PARENTAL...			
expectations for learner achievement	50	45	61
involvement in school activities	24	23	26
commitment to ensure that learners are ready to learn	17	13	24*
support for learner achievement	15	12	24*
LEARNERS'...			
respect for classmates who excel academically	42	38	51
desire to do well in school	34	31	40
ability to reach school's academic goals	29	24	39*

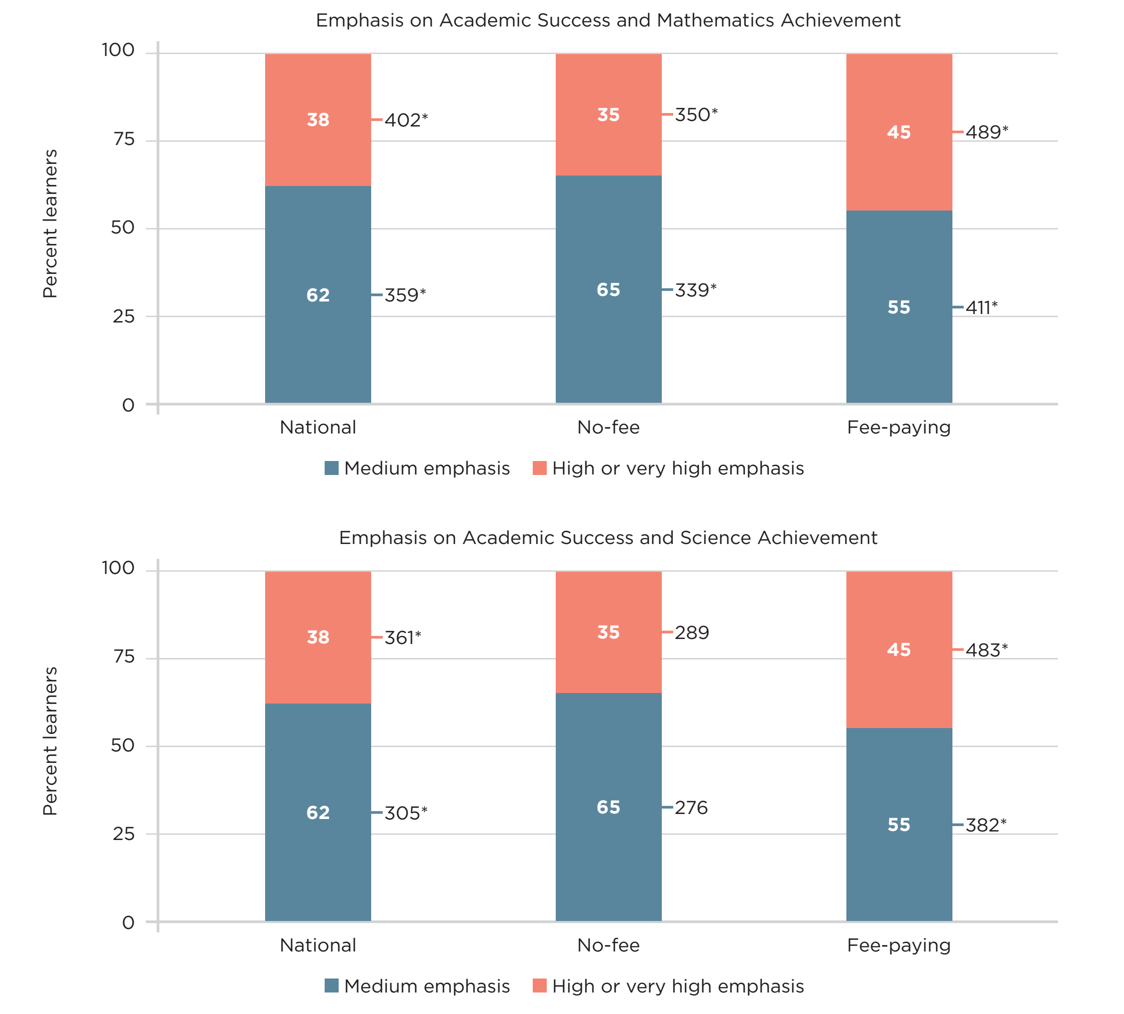
* Statistically significant difference between no-fee and fee-paying schools.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

Based on the above set of items, TIMSS created a *School Emphasis on Academic Success Scale*[31]. Figure 43 reports the percentage of learners attending fee-paying and no-fee schools 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.

31 See Mullis et.al. (2020) for a description School Emphasis on Academic Success Scale (Page 343). Exhibit 7.1.

Figure 43: Emphasis placed on academic success and achievement, by school fee-status



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 dataset.

Nationally, 38 percent of learners attended schools that placed a 'very high' or 'high' emphasis on academic success, compared with the international average of 62 percent. Only four percent of learners attended schools that placed a 'very high' emphasis on academic success. 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 (402 versus 359 for mathematics, and 361 versus 305 for science).

One-third of learners in no-fee schools attended schools that placed a 'high' or 'very high' emphasis on academic success compared to almost half in fee-paying schools. In fee-paying schools, we observed significantly different mathematics and science achievement between schools that placed a higher emphasis on academic success and those that placed less emphasis. However, in no-fee schools the level of emphasis placed on academic success was significantly different for mathematics but not for science, where the performance was very low.

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 and PIRLS 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, Arends & Beku, 2018).

TIMSS asked educators to report on various characteristics of their schools' safety and discipline. Table 24 reports responses from mathematics educators[32] about the presence of the characteristics of safe and orderly schools in their own schools.

While seven in ten learners were in schools reported to have clear rules about learner conduct, only half the learners were in schools where the rules were enforced in a fair and consistent manner according to educators. Educators expressed their concerns about safety in schools, with only 42 percent of the learners' attending schools that were reported to be located in a safe neighbourhood, and 45 percent where educators felt safe. Educators also expressed concerns about the behaviour of learners, with only 28 percent of learners being respectful of educators, 22 percent reported to behave in an orderly manner, and 18 percent respecting school property.

Within the of low levels of safety and orderliness in schools, learners in both no-fee and fee-paying schools experienced similar school climates and levels of unsafe conditions, except for one characteristic: significantly more no-fee learners, than fee-paying learners, attended schools rated as located in safe neighbourhoods.

Table 24: Mathematics educator responses to the characteristics of safe and orderly schools (by percentage of learners)

Characteristics	Percent learners in schools rated 'Agree a lot'		
	National	No-fee	Fee-paying
The school has clear rules about learner conduct	71	68	77
The school's rules are enforced in a fair and consistent manner	56	59	49
I feel safe at this school	45	46	44
The school is located in a safe neighbourhood	42	47*	33
The school's security policies and practices are sufficient	32	31	34
The learners are respectful of teachers	28	28	27
The learners behave in an orderly manner	22	19	29
The learners respect school property	18	18	16

* Statistically significant difference between no-fee and fee-paying schools.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

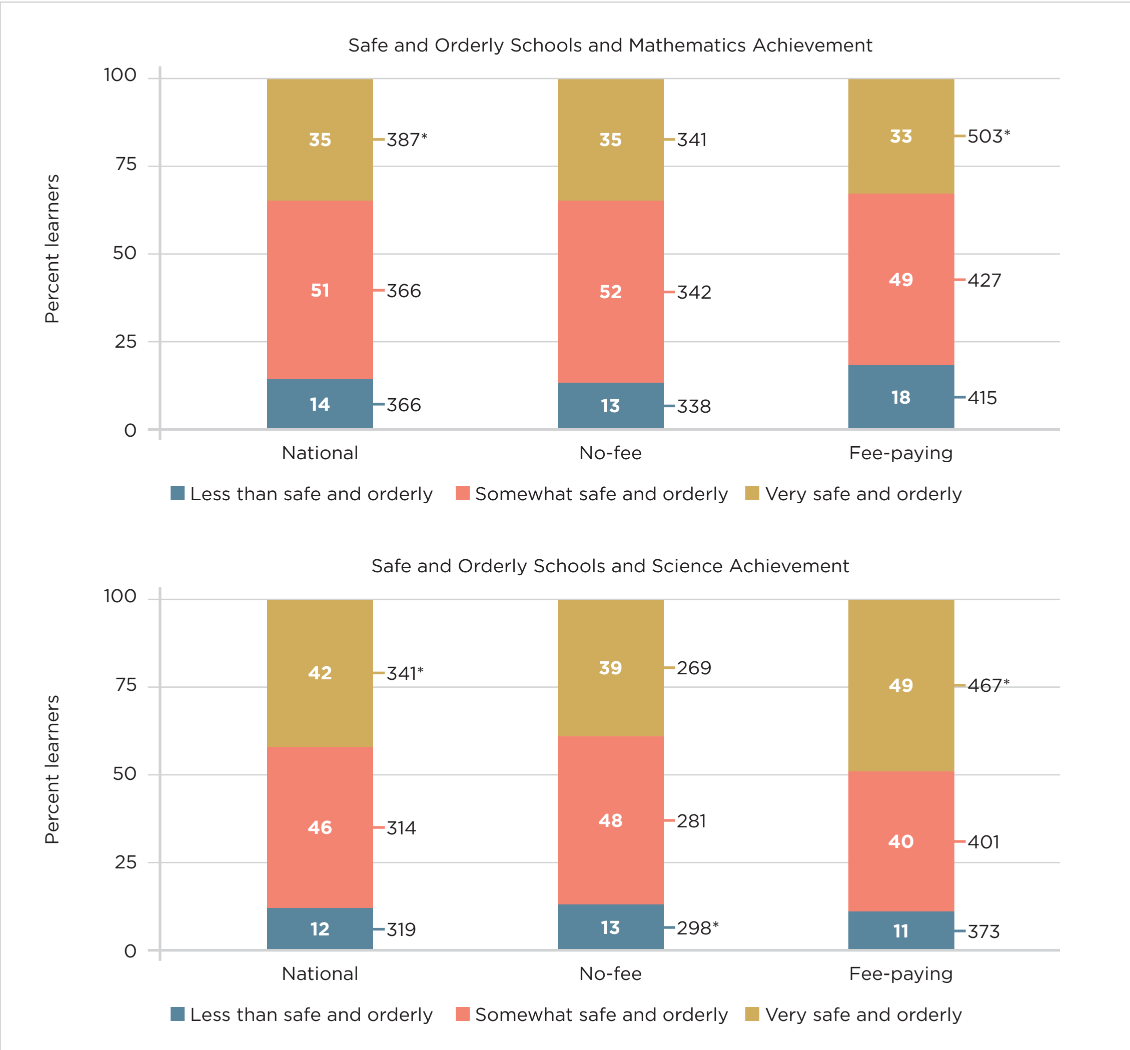
32 The responses from science educators were similar.

TIMSS 2019 used these eight characteristics to create a *Safe and Orderly School Scale*[33]. 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 44 reports the relationship between the extent to which schools were considered as safe and orderly, and achievement by school fee-status. Nationally, 35 percent of learners attended schools that were 'very safe and orderly', with the majority of learners in schools that were 'somewhat safe and orderly' (51%). Internationally, 61 percent of learners were in schools considered to be 'very safe and orderly', and 36 percent were in schools that were 'somewhat safe and orderly'.

Nationally, learners in schools considered to be safer and more orderly significantly outperformed learners that were in schools characterised as less safe and orderly (387 versus 366 for mathematics, and 341 versus 319 for science). This achievement pattern was apparent in fee-paying schools but was absent in no-fee schools.

Figure 44: Safe and orderly schools and achievement, by school fee-status



* Statistically significant achievement differences between categories.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

33 See Mullis et al. (2020) for a description of the Safe and Orderly School Scale (Page 365).

School discipline

For schools to be effective, an orderly environment must be ensured through fair and positive discipline that promotes appropriate learner behaviour. Simeon and Lepka Favour (2020: 96) defined discipline as "the ability to carry out reasonable instructions or orders to reach appropriate standards of behaviours". If there is good discipline at school, disruptive behaviour among learners is minimised. However, learner indiscipline has been repeatedly reported as a problem within South African schools (Pretorius, 2014).

Principals were asked to what extent the ten behaviours listed in Table 25 were a problem among learners in their schools. We report on the percentage of learners attending schools that experienced 'severe problems'.

Just over 10 percent of learners attended schools where there were high incidences of vandalism, classroom disturbances, fights among learners and theft. Within this environment, learners in both no-fee and fee-paying schools experienced similar levels of poor discipline, except for one characteristic: there were significantly higher levels of physical fights in no-fee schools.

Table 25: Principal responses to poor discipline behaviours in schools (by percentage of learners)

Behaviours in school	Percent learners in schools rating each behaviour a 'severe problem'		
	National	No-fee	Fee-paying
Vandalism	13	16	9
Classroom disturbance	11	12	9
Physical fights among learners	11	15*	2
Theft	11	12	9
Intimidation or verbal abuse among learners	8	8	6
Profanity	7	6	9
Intimidation or verbal abuse of educators or staff	4	4	4
Arriving late at school	4	4	3
Absenteeism	4	4	3
Cheating	1	2	0

* Statistically significant difference between no-fee and fee-paying schools.

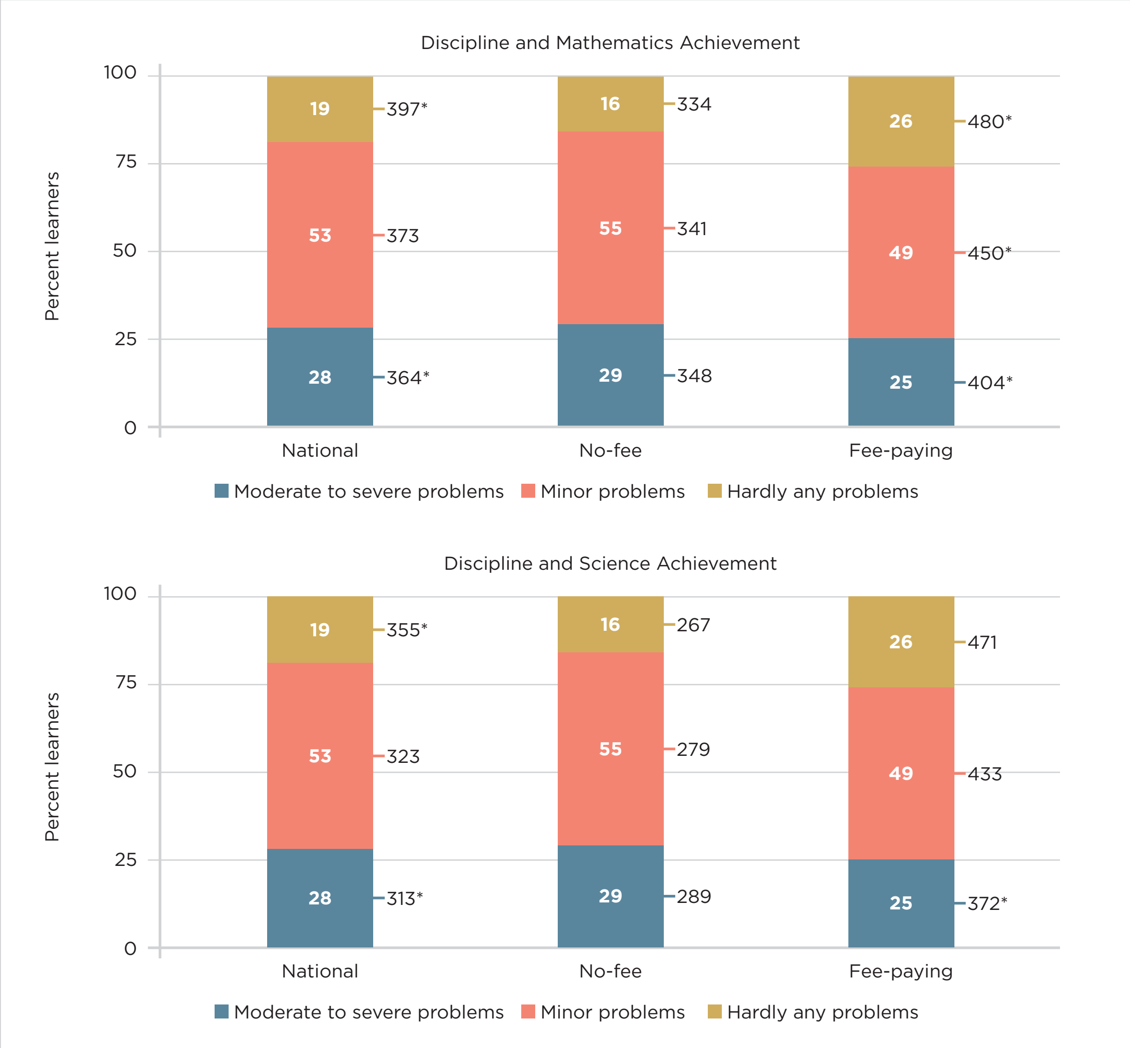
Source: Authors' own calculations from TIMSS 2019 dataset.

TIMSS used these ten behaviours to create a *School Discipline Scale*[34]. Three categories were included in the scale: 1) *moderate to severe* problems, 2) *minor* problems, and 3) *hardly any* problems. Figure 45 reports on the relationship between school discipline and achievement by school fee-status. Twenty-eight percent of South African learners attended schools where the principals reported 'moderate to severe problems' in comparison with the international average of eight percent.

Nationally, learners who attended schools with 'hardly any' discipline problems significantly outperformed learners in schools with 'moderate to severe' problems (397 versus 364 for mathematics, and 355 versus 313 for science). This pattern was replicated in fee-paying schools. In no-fee schools, there was no association between the extent of discipline problems experienced and mathematics and science achievement.

34 See Mullis et al. (2020) for a description of the School Discipline Scale (Page 359).

Figure 45: Learners' experience of school discipline and achievement, by school fee-status



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

Incidences of bullying in schools

Bullying involves repeated aggressive behaviour intended to harm another individual. It can take a variety of forms within the school environment, such as name-calling or inflicting physical harm (Winnaar et al., 2018). Bullying is related to school climate, with less incidences of bullying being associated with a positive school climate (Juan, Zuze, Hannan, Govender & Reddy, 2018). Previous TIMSS reports have shown that bullied learners tend to have lower mathematics and science achievement, aligning with the findings of other research (Rothon, Head, Klineberg & Stansfeld, 2011; Rutkowski, Rutkowski & Engel, 2013).

TIMSS 2019 Grade 5 learners reported how often they experienced bullying behaviours (physical, verbal or cyber bullying) at school. We report the percentage of learners who *never or almost never* experienced bullying (Table 26). Overall, between a half and two-thirds of learners did not experience any form of verbal or physical bullying, and three-quarters of learners did not experience cyber bullying. However, on every item, learners in no-fee schools experienced significantly higher levels of verbal, physical and cyber bullying than learners in fee-paying schools.

Table 26: Percentage of learners who were never or almost never bullied, by school fee-status

Behaviours	Percent learners 'never or almost never bullied'		
	National	No-fee	Fee-paying
Verbal			
Left me out of their games or activities	61	56	72*
Spread lies about me	59	56	64*
Made fun of me or called me names	54	51	59*
Physical			
Made me do things I didn't want to do	69	65	78*
Threatened me	68	64	76*
Damaged something of mine on purpose	63	59	71*
Hit or hurt me (e.g. shoving, hitting, kicking)	63	60	70*
Stole something from me	50	46	59*
Cyber			
Shared embarrassing photos of me online	76	71	87*
Sent me nasty or hurtful messages online	75	71	83*
Shared nasty or hurtful messages about me online	75	71	84*

* Statistically significant difference between no-fee and fee-paying schools.

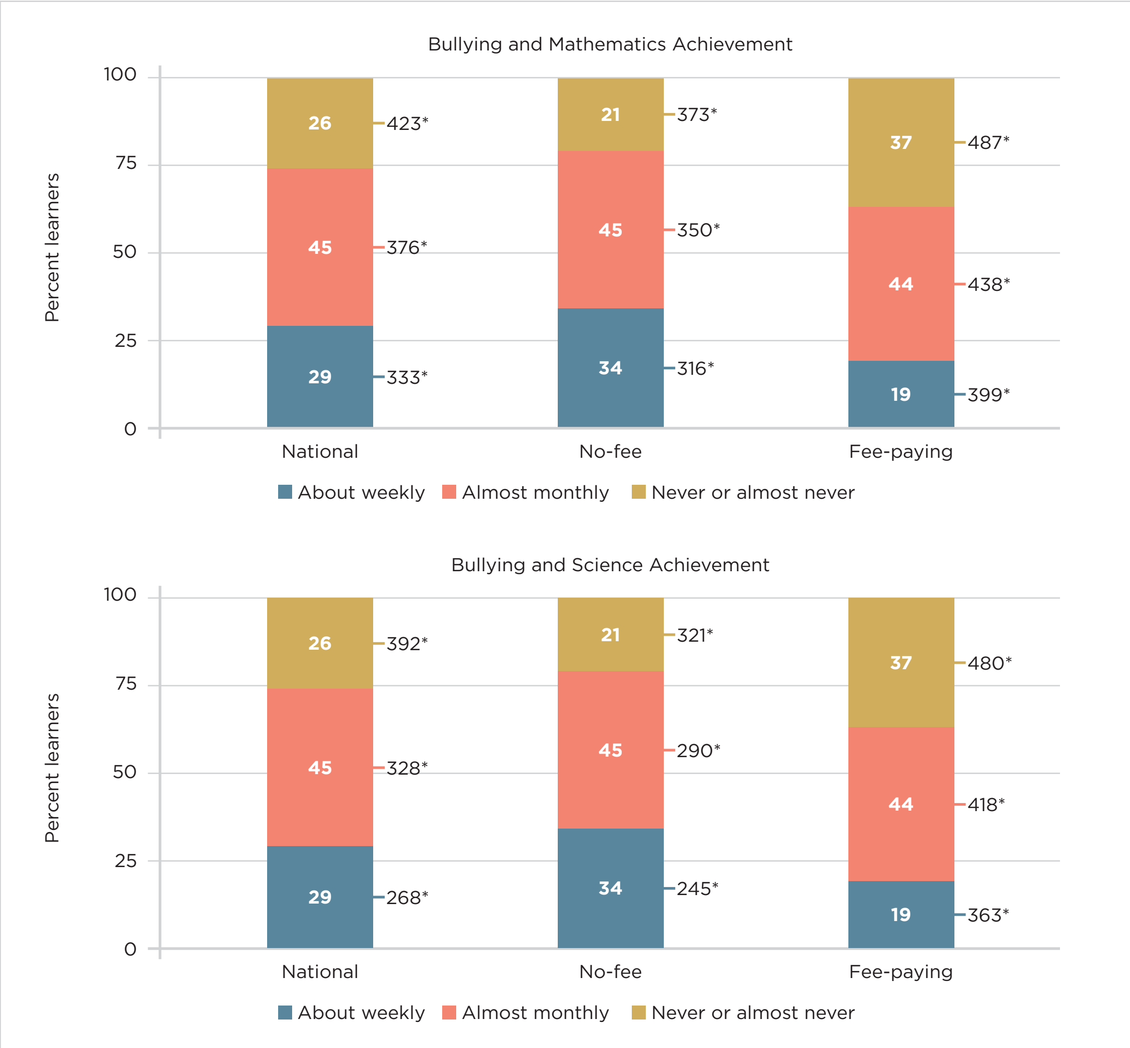
Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

TIMSS 2019 used these 11 behaviours to create a *Learner Bullying Scale*[35]. The scale used three categories: 1) bullied *about weekly*, 2) bullied *almost monthly*, and 3) *never or almost never* bullied.

Figure 46 reports on the relationship between bullying and achievement by school fee-status. South Africa experienced higher levels of bullying than most participating countries. Only a quarter (26%) of South African Grade 5 learners reported 'never or almost never' being bullied, compared to the international average of 63 percent.

At the national level, as well as in no-fee and fee-paying schools, learners who hardly experienced any form of bullying achieved significantly higher mathematics and science scores than learners who experienced bullying 'about weekly' (423 versus 333 for mathematics, and 392 versus 268 for science). The score differences between the best and worst scenario, in this case where learners reported being bullied, was bigger than that for other school safety measures reported by educators or the principal.

Figure 46: Learner experiences of bullying and achievement, by school fee-status



* Statistically significant achievement difference between categories.

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

The following infographic summarises the aspects of schools creating enabling learning environments in the TIMSS 2019 Grade 5 study.

35 See Mullis et al. (2020) for a description Learner Bullying Scale (Page 374).

7.4. SUMMARY: SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

Home to school continuities

Parents and society view schools and classrooms as the institution best placed to equalise learning opportunities for learners from poorer homes and to level the playing field of educational success.

However, there is a continuity of socioeconomic conditions from homes to schools. On the one hand, learners who are from low-income households largely attended no-fee schools with limited access to resources and poor teaching and learning conditions. Learners from more affluent households largely attended fee-paying schools with better teaching and learning conditions.

School characteristics

Two-thirds of learners in no-fee schools, compared with a quarter of learners in fee-paying schools, came from low SES households. Learners in Quintile 1, 2 and 3 schools were almost exclusively Black African.

The population of learners was almost equally distributed in each of the following three geo-locations: big and medium cities and suburbs, small towns or villages, and 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 remote rural areas.

The school geolocation profile was different for no-fee and fee-paying schools: three-quarters of learners in fee-paying schools attended schools located in big and medium cities and suburbs, compared to a quarter of no-fee learners. Just under half of the learners in no-fee schools attended schools in remote rural areas.

School climate: Emphasising academic success

A positive school atmosphere with high expectations for academic excellence can contribute to the success of a school. Principals rated the mathematics and science educators highly on aspects emphasising academic success but were less enthusiastic about parent and learner contributions to these aspects.

In South Africa, four in ten learners attended schools that placed a high emphasis on academic success. Learners who attended schools that placed a higher emphasis on academic success scored, on average, significantly higher than learners who attended school that did not place much emphasis on academic achievement.

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

A well-performing school is one that provides a safe and orderly space for both learners and educators. Four in ten learners attended schools that educators categorised as very safe and orderly. School discipline problems were widespread, with only one in five learners attending schools that principals characterised as having hardly any problems. Learner bullying was also widespread, and three in four learners reported that they experienced incidences of bullying in schools.

On all school climate factors, South Africa, when compared with other TIMSS participating countries, reported higher levels of negative behaviours and cultures.

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 safer schools with hardly any discipline problems, and who hardly experienced any form of bullying, achieved significantly higher mathematics and science scores.

The next chapter focuses on what happens in classrooms, exploring educator characteristics, the availability of resources and instructional practices.

CHAPTER EIGHT

CLASSROOMS – EDUCATORS, RESOURCES AND INSTRUCTIONAL PRACTICES

The majority of teaching and learning for children and young people 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 of structuring the learning process to start where the learner is and completing the learning outcomes designed for that grade.

In this chapter we report on:

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

8.1. EDUCATORS

Preparation and experience

Prospective educators need adequate preparation to gain the relevant 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; Douglas, 2017). 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 (Didion, Toste & Filderman, 2020).

Table 27 describes the percentage of learners taught by educators by their demographics of gender, age, teaching experience, educational qualifications, subject specialisation and job satisfaction levels.

Table 27: Percentage of learners taught by educators with each characteristic

	Mathematics educators	Science educators
Gender		
Taught by female educators	65 (3.5)	63 (2.6)
Taught by male educators	35 (3.5)	37 (2.6)
Educator age		
Less than 30 years	13 (2.2)	18 (2.9)
30-39 years	16 (2.5)	14 (1.8)
40-49 years	32 (3.8)	27 (3.0)
Over 50 years	39 (4.4)	41 (4.2)
Average teaching experience	**17 years**	**16 years**
Educational qualification		
Finished Grade 12	5 (1.5)	6 (1.7)
Finished Diploma	33 (3.0)	37 (3.2)
Finished First degree	35 (2.7)	37 (3.3)
Finished Honours or higher	27 (3.3)	20 (3.1)
Subject specialisation	**67 (4.0)**	**53 (3.8)**
Very satisfied in their jobs	**64 (3.4)**	**68 (3.5)**

Source: TIMSS 2019 South African Grade 5 dataset.

Close to two-thirds of learners were taught mathematics and science by a female educator. The average teaching experience of South African mathematics educators was 17 years, and for science educators it was 16 years, close to the international average of 17 years for both subjects. Close to 70 percent of learners were taught by educators older than 40 years of age. This high percentage of educators over 40 years should be a signal of concern for the pipeline of educators in the South African education system.

There is a body of evidence showing that educators' subject knowledge and experience are related to learner achievement (Arends et al., 2017; Lay & Chandrasegaran, 2018). The self-reported formal education of educators showed that around four in ten mathematics (38%) and science (44%) learners were taught by educators without a Bachelor's degree qualification (i.e. with either a Grade 12 certificate or a diploma) while six in 10 learners were taught by educators with a Bachelor's degree or higher qualification (62% for mathematics and 57% for science). The comparative international average statistic for mathematics and science educators with less than a Bachelor's degree qualification was only 15 percent.

Two-thirds of mathematics learners (67%) and half of science learners (53%) were taught by educators who reported a subject specialisation in mathematics or science. This information does not corroborate with responses from the principals regarding educators' subject matter knowledge. We were unable to confidently corroborate educators' qualifications and specialisations with other data. The Sustainable Development Goals: South African Country Report 2019 reported that 91 percent of educators had the minimum required qualifications of either a three-year teachers' diploma or a three-year degree (StatsSA, 2019).

The profiles of mathematics and science educators, in terms of the variables listed above, were similar in both no-fee and fee-paying schools.

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 learners' needs. In addition, educators were asked about their *need* for future professional development in the same areas.

Figure 47 reports the percentage of learners taught by mathematics and science educators in relation to their recent professional development participation and future needs. The professional development programmes would largely have been coordinated by the provincial and district level education authorities.

Most of the mathematics and science professional development activities that educators participated in related to curriculum, content and assessment – these are important interventions in the context of poor achievement. There was less participation in activities relating to integrating technology into instruction and addressing individual learners' needs. The integration of technology in instruction 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 more activities related to integrating technology into instruction, addressing individual learners' needs, improving learners' critical thinking or problem-solving skills, and pedagogy and instruction.

Figure 47: Percentage of learners by educators' recent participation in, and need for, professional development activities

Professional development activities	Mathematics educators		Science educators	
	Participation in professional development	Need for professional development	Participation in professional development	Need for professional development
Content	85	70	68	78
Curriculum	85	68	76	74
Assessment	78	73	62	74
Improving learners' critical thinking or problem-solving skills	67	84	60	81
Addressing individual learners' needs	60	83	54	79
Pedagogy/instruction	57	78	46	75
Integrating technology into instruction	46	83	59	78

Source: TIMSS 2019 South African Grade 5 dataset.

Educators were also asked when the professional development activities usually take place. Forty-three percent of educators reported that the activities took place during school hours, one-third (35%) after school and a quarter (23%) on weekends or during school holidays. The implication of professional development activities being 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

The Department of Basic Education (DBE) defines class size as "The average number of learners per class, calculated by dividing the number of learners enrolled by the number of classes" (DBE, 2011c: 20). According to the Personnel Administrative Measures (PAM) Government Gazette, the ideal maximum Grade 5 class size is 40 learners (DBE PAM, 2016). The Action Plan to 2024 (DBE, 2020a) raises a concern about the large class sizes in South African schools and the implications for learning.

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 added to the learner dataset. We included the total number of learners as a class size variable in the TIMSS dataset, which included learner and school information, as well as the mathematics and science achievement plausible values.

The global research shows that changing the average class size makes only a small difference to achievement, and Filges, Sonne-Schmidt and Nielsen (2018) argue that while learner achievement may be improved by reducing class size, bigger class sizes aid in the management of educational budgets. There is less known about class size effects in low-income countries where there are very big classes.

In low-income countries, the starting position is that a classroom should not have more than 40 learners and it would be almost impossible to have effective teaching and learning if over 50 learners were in a classroom designed for 40 learners, while the educator is asked to provide individual attention in an overcrowded classroom.

Table 28 reports the average TIMSS 2019 Grade 5 class sizes, by the quintiles of public schools, and for independent schools.

Table 28: Average class size (with standard deviation) for national, Quintiles 1-5, and independent schools in TIMSS sample

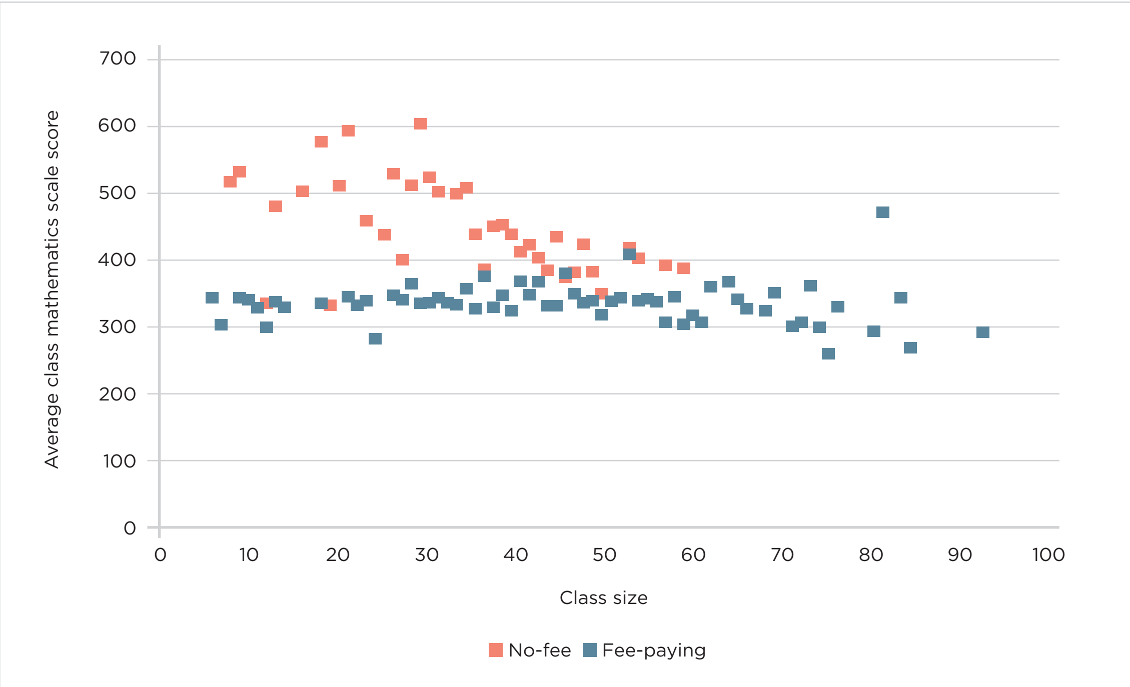
	National (SD)	Quintile					Independent (SD)
		1 (SD)	2 (SD)	3 (SD)	4 (SD)	5 (SD)	
Class size: average number of learners	44 (14.2)	44 (17.5)	48 (15.6)	48 (11.6)	43 (8.2)	35 (7.0)	30 (12.1)

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

The average national TIMSS 2019 Grade 5 class size was 44 learners. Quintile 1, 2 and 3 schools had higher average class sizes, with the no-fee school group having an average of 47 learners per class. Quintile 4 schools had slightly smaller class sizes, while Quintile 5 and independent schools had smaller average class sizes at 43 learners, 35 learners and 30 learners per class, respectively. The average number of learners per class in fee-paying schools was 38 learners. The TIMSS class size ranged from six to 91 learners in no-fee schools, and eight to 58 learners in fee-paying schools.

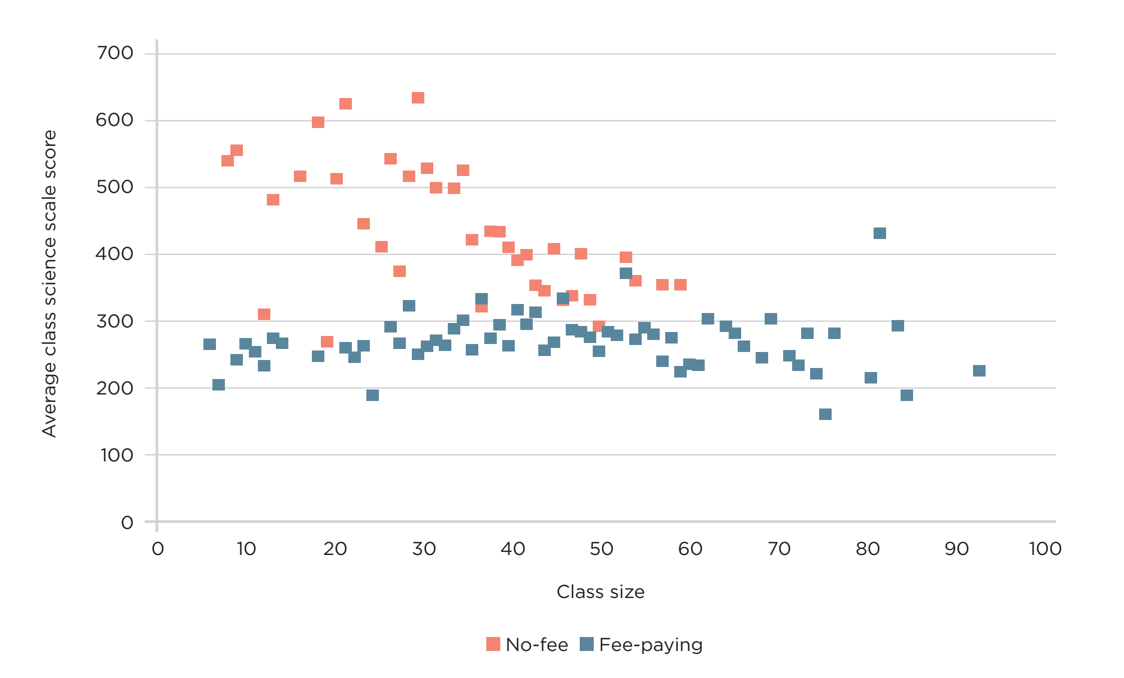
In order to explore the relationship between class size and achievement, we calculated the average mathematics and science achievement for each TIMSS class. Figure 48 and Figure 49 presents the scatterplots of TIMSS 2019 class sizes and achievement for no-fee and fee-paying schools for mathematics and science. The achievement scores for learners in no-fee classes were lower than that for fee-paying classes. These scatterplots also illustrate the point that there was hardly any achievement variation (more so for mathematics) among classes in no-fee schools, and thus there was no correlation between class size and achievement. There was higher achievement variation among classes in fee-paying schools, and learners in schools with smaller class sizes achieved higher mathematics and science scores.

Figure 48: Average class mathematics scale score, by class size and school fee-status



Source: Authors' own calculations from TIMSS 2019 dataset.

Figure 49: Average class science scale score, by class size and school fee-status

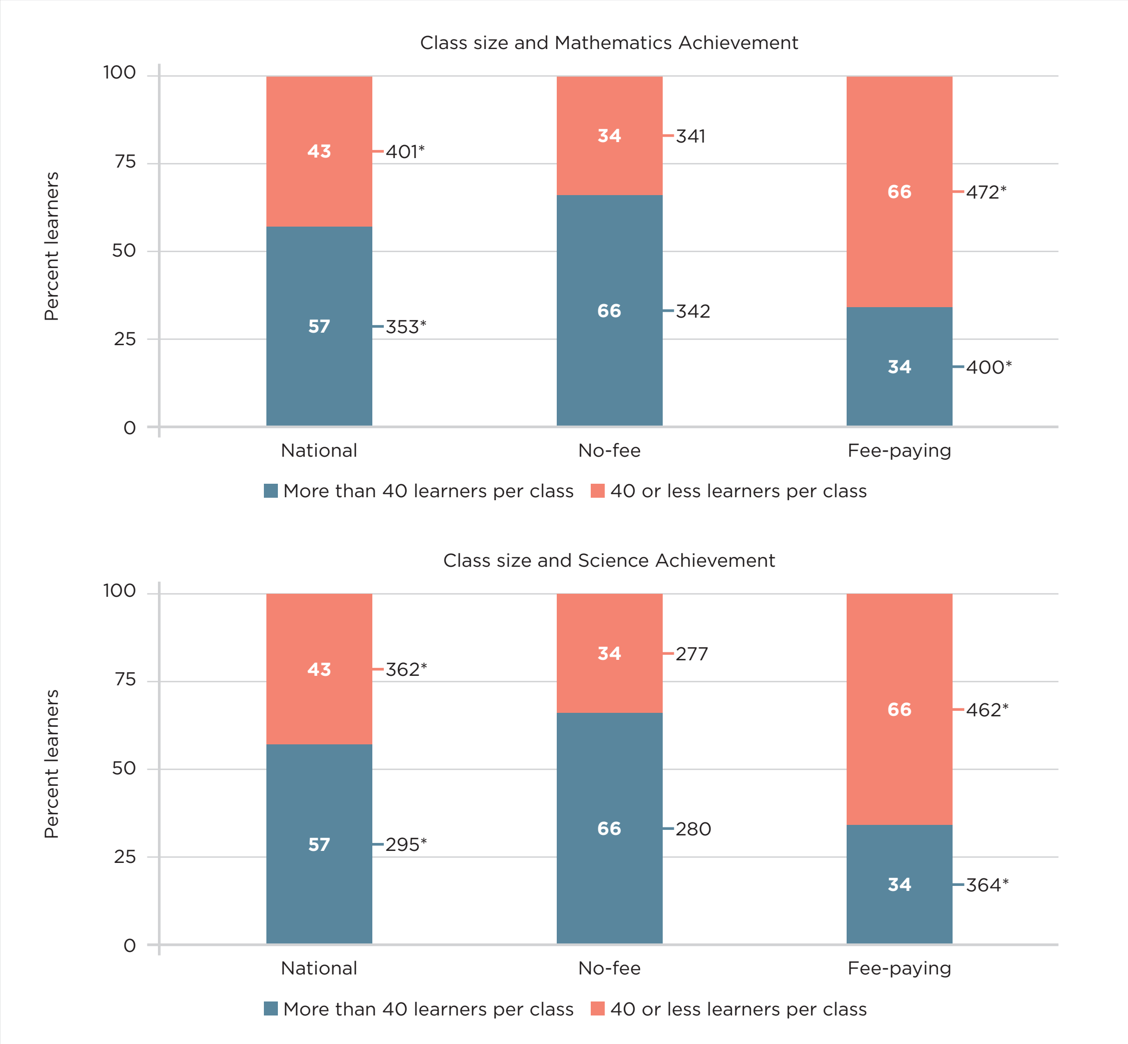


Source: Authors' own calculations from TIMSS 2019 dataset.

We explored the association between class size, and mathematics and science achievement further for South Africa, and for no-fee and fee-paying schools. In no-fee schools only one-third (34%) of learners were in classes with less than 40 learners, while in fee-paying schools, two-thirds (66%) of learners were in classes of this size.

Learners in classes with less than 40 learners scored higher average mathematics and science achievement than those in classes with more than 40 learners (401 versus 353 for mathematics, and 362 versus 295 for science) (Figure 50). We observed the same pattern for learners in fee-paying schools, but there was no achievement difference in no-fee schools. No-fee schools experience multiple disadvantages that interact with each other, and hence it is difficult to isolate single factors that are related to achievement.

Figure 50: Class size and achievement, by school fee-status



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 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 29 reports principals' ratings of how instruction in their schools was affected by the availability of mathematics and science resources.

According to the principal reports, close to half of the learners attended schools that were affected by shortages of educators with specialisations in mathematics and science, a lack of concrete objects to learn mathematics and science equipment to conduct experiments, and a lack of library resources relevant to mathematics and science instruction. Surprisingly, only 46 percent of learners were reported to be affected by a lack of computer software and applications for mathematics and science instruction. Given the lack of computers in schools (see Section 8.4 of this chapter) we expected a higher percentage of learners to be affected. We were also surprised that 44 percent of learners were still affected by a shortage of calculators – a resource that educational authorities are supposed to provide to schools.

Table 29: Percentage of learners attending schools where the principal reported instruction was affected

Resources for mathematics	Percent learners affected substantially[36]	Resources for science	Percent learners affected substantially
Educators with specialisation in mathematics	52	Educators with specialisation in science	49
Concrete objects or materials to help learners understand quantities or procedures	51	Science equipment and materials for experiments	50
Library resources relevant to mathematics instruction	47	Library resources relevant to science instruction	43
Computer software/applications for mathematics instruction	46	Computer software/applications for science instruction	46
Calculators for mathematics instruction	44	*No equivalent item for science*	

Source: TIMSS 2019 South African Grade 5 dataset.

Workbooks

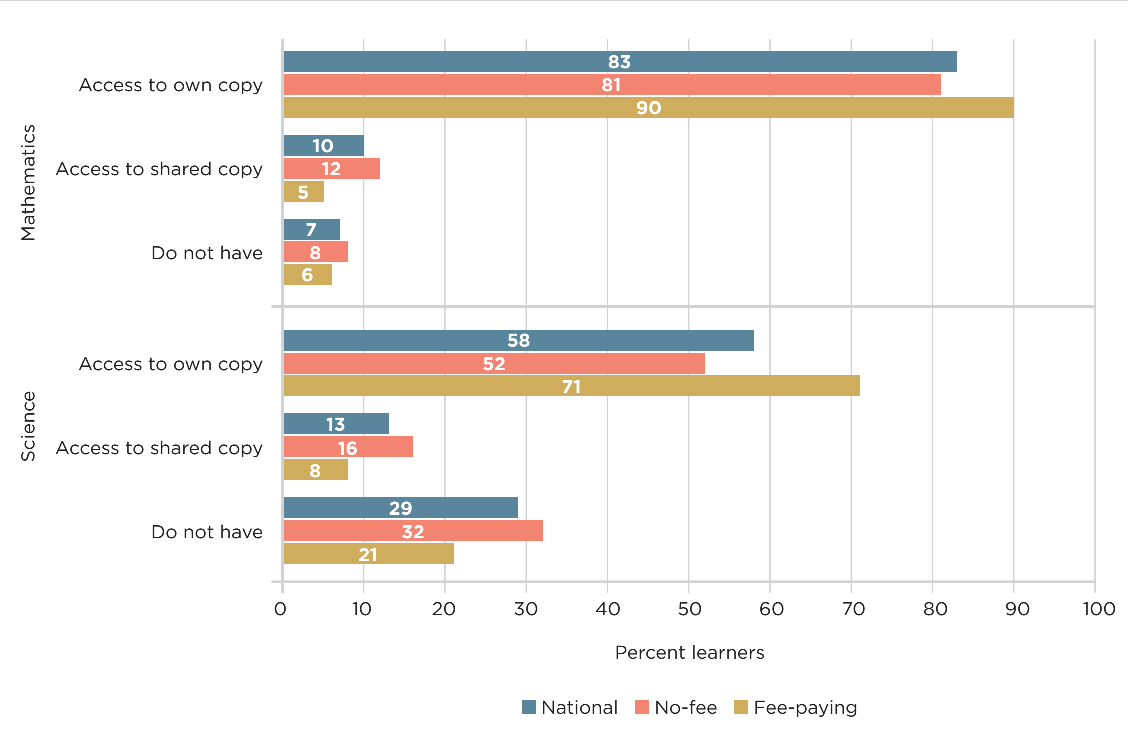
A key teaching and learning resource in the classroom are workbooks. The DBE developed a range of workbooks for Grade 1 to 6 learners to improve their literacy and numeracy skills (DBE, 2020a). Figure 51 reports on the availability of mathematics and science workbooks for Grade 5 learners.

Learner access to mathematics workbooks was better than for science. More than 90 percent of mathematics learners said that they had access to their own or a shared workbook, with access being similar in no-fee and fee-paying schools. These reports aligned with the School Monitoring Survey 2017/2018 (DBE, 2018), which reported that 84 percent of Grade 6 learners had access to a mathematics textbook.

Three in ten learners reported that they did not have access to a science workbook. The picture was slightly better in fee-paying than in no-fee schools, with 21 percent and 32 percent of learners, respectively, reporting that they did not have any access to a science workbook.

36 Responses by principal of 'Some' or 'A Lot' were combined to form 'Substantial'.

Figure 51: Access to mathematics and science workbooks, by school fee-status



Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Next, we combined the categories of learners sharing workbooks with classmates and those who did not have these resources[37], to establish the association with achievement for those who reported having their own workbooks (Table 30). Nationally, and in both no-fee and fee-paying schools, learners who had their own workbook achieved significantly higher mathematics scores than those who shared or did not have workbooks. For science, this pattern was similar nationally and in fee-paying schools, but due to the very low science scores with very little variation in no-fee schools, we did not observe any significant differences.

Table 30: Association between access to workbooks and achievement

	National	No-fee	Fee-paying
Learner access to mathematics workbook			
Access to own copy	386*	352*	454*
Shared or did not have	326*	309*	397*
Learner access to science workbook			
Access to own copy	348*	283	456*
Shared or did not have	298*	279	368*

* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

37 The difference in the achievement scores of learners in these two categories was not significant.

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 took place inside classrooms by reporting on (i) instructional clarity from the perspective of educators and learners; (ii) learner behaviour in classrooms; and (iii) emphasis on science investigations as reported by the educators.

Educators' instructional clarity

Classroom instruction and educator engagement are at the core of the learning process (Nilsen & Gustafsson, 2016). Instructional clarity encourages the gradual transfer of learning responsibility from the educator to the learners, allowing learners to take ownership of their own work. Hattie (2011), based on a meta-analysis of a number of studies on instructional clarity, concluded that educator clarity in the form of feedback is one of the most important strategies to use in classrooms. We report on instructional clarity in classrooms from the perspectives of educators and learners.

Burroughs et al. (2019) describes instructional clarity in two dimensions – cognitive activation and supportive climate. 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). We categorised the TIMSS items into the two dimensions of instructional clarity, namely, cognitive activation and a supportive learning environment.

Table 31 reports the extent to which mathematics and science educators employed the elements of instructional clarity in half or more lessons. Overall, most learners were taught by educators who reported that they frequently employed these strategies in their lessons.

Table 31: Percentage of learners by educators' rating of their instructional clarity

Elements of Instructional Clarity	Percent learners experiencing strategy in 'half or more lessons'	
	Mathematics	Science
Cognitive activation		
Ask learners to explain their answers	83	85
Relate the lesson to learners' daily lives	80	86
Ask learners to decide their own problem-solving procedures	69	68
Bring interesting materials to class	66	77
Ask learners to complete challenging exercises that require them to go beyond the instruction	57	60
Supportive climate		
Link new content to learners' prior knowledge	93	94
Encourage learners to express their ideas in class	85	89
Encourage classroom discussions among learners	73	79

Source: TIMSS 2019 South African Grade 5 dataset.

The TIMSS learner questionnaire also asked learners to rate their educators' instructional clarity on a number of statements (Table 32). The rating by learners, though slightly lower than that by the educators, was still positive with over two-thirds of learners agreeing with each statement.

Table 32: Learners' ratings of Instructional Clarity for mathematics and science

Elements	Percent of learners who 'Agree a lot'	
	Mathematics	Science
My educator is good at explaining mathematics/science	77	72
I know what my educator expects me to do	74	71
My educator explains a topic again when we don't understand	73	69
My teacher has clear answers to my questions	68	66
My educator does a variety of things to help us learn	70	65
My educator is easy to understand	64	64

Source: TIMSS 2019 South African Grade 5 dataset.

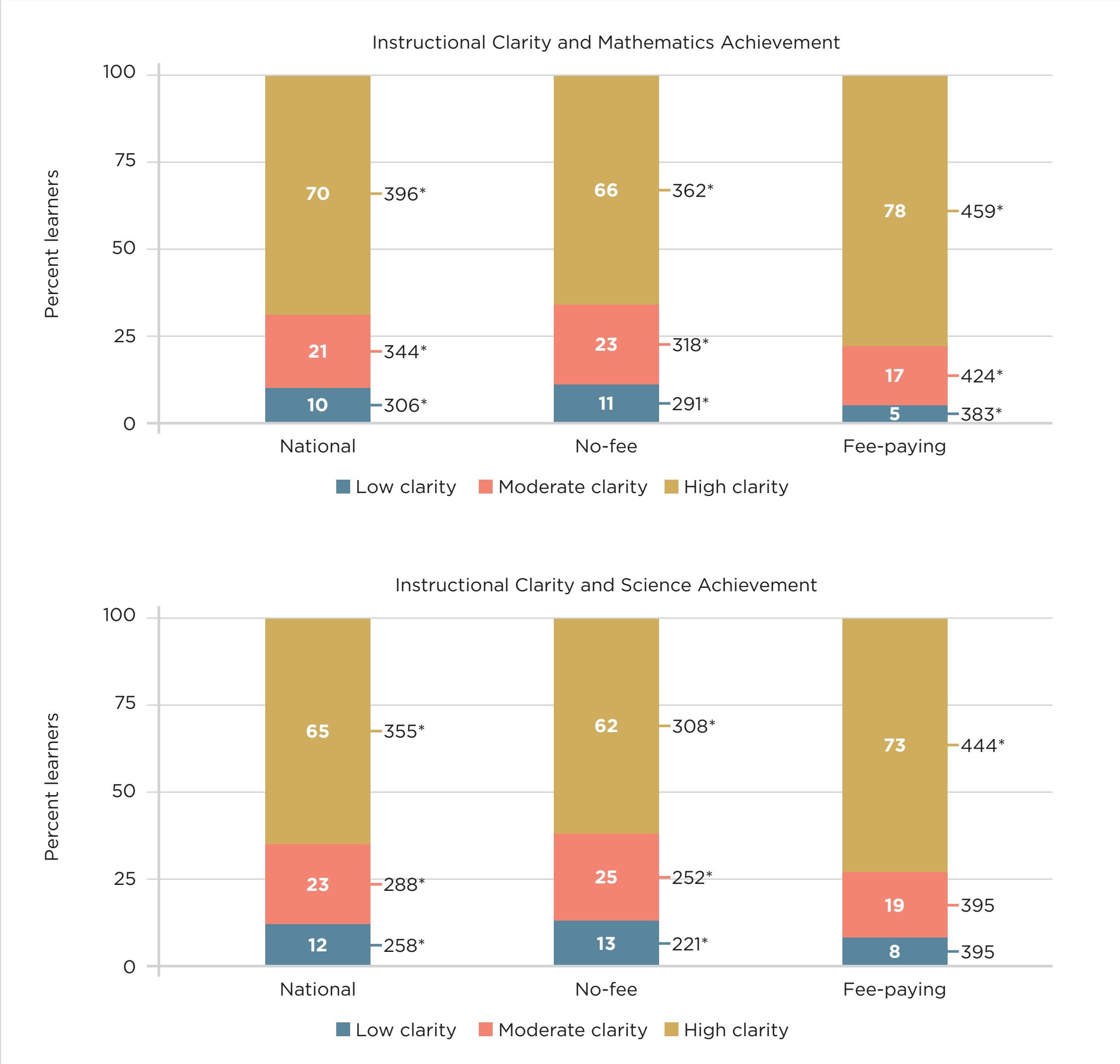
TIMSS created an *Instructional Clarity Scale* based on learner responses to the six items[38]. The scale comprised three categories: 1) *low clarity* of instruction, 2) *medium clarity* of instruction, and 3) *high clarity* of instruction. Figure 52 reports the association between clarity of instruction, and mathematics and science achievement.

On average, 70 percent of mathematics learners and 65 percent of science learners reported 'high' clarity of instruction in their classes. The comparable international average was 74 percent for mathematics and 72 percent for science. Learners who reported 'high' instructional clarity in mathematics and science lessons achieved significantly higher scores than those who reported 'moderate' and 'low' instructional clarity: for mathematics learners reporting 'high' versus low instructional clarity scored 396 versus 306. For science the corresponding scores were 355 versus 258.

The significant relationship between instructional clarity and achievement was observed in both no-fee and fee-paying schools.

38 See Mullis et al. (2020) page 459 for mathematics and page 477 for science for a description of the Instructional Clarity Scale.

Figure 52: Instructional Clarity and achievement, by school fee-status



* Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

Learner behaviour during mathematics lessons

Classroom management and discipline are complex matters that educators and school management teams must address. Educators have to spend time managing disruptive behaviour while also meeting set instructional goals (Lopes & Oliveira, 2017). Strong links have been established between learner behaviour and academic achievement, with positive behaviour being associated with higher academic achievement (Engzell, Frey & Verhagen, 2021; Lopes & Oliveira, 2017; Simeon & Nnaa, 2020).

Grade 5 learners were asked six questions about the frequency of disorderly behaviour during their mathematics lessons. Table 33 reports the percentage of learners who experienced this behaviour in almost every lesson.

Half the learners reported that the educator had to tell the class to follow classroom rules in almost every lesson and close to four in ten learners experienced disruptive behaviours like waiting for learners to quiet down, learners interrupting the educator and not listening to what the educator said. One-third of learners reported that it was too disorderly for them to work well, and there was disruptive noise in almost every lesson.

Table 33: Elements that constitute disorderly behaviour during mathematics lessons

Disorderly behaviour during mathematics lessons	Percent learners experiencing the behaviour in 'almost every lesson'
My educator has to keep telling us to follow the classroom rules	53
My educator has to wait a long time for learners to quiet down	39
Learners don't listen to what the educator says	39
Learners interrupt the educator	37
It is too disorderly for learner to work well	36
There is disruptive noise	35

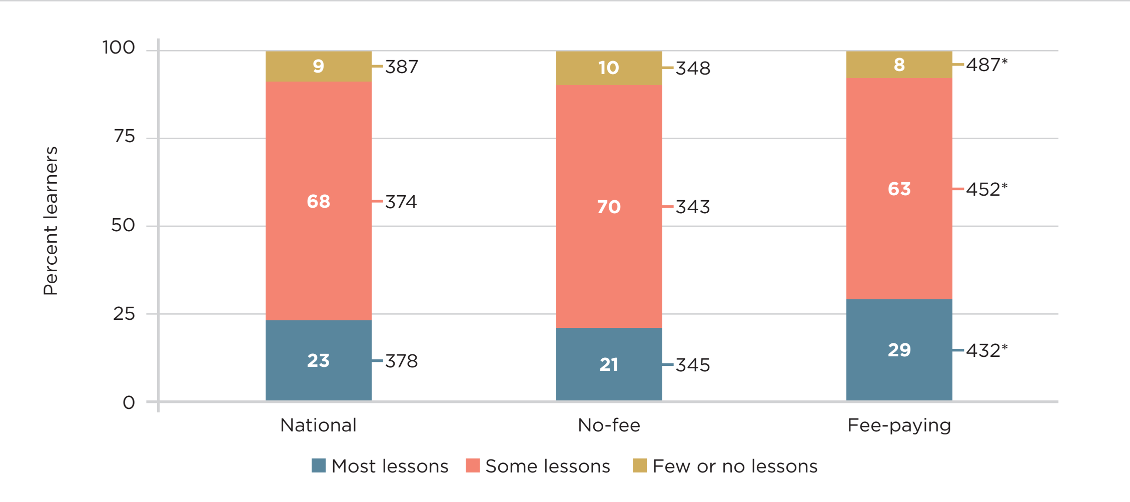
Source: TIMSS 2019 South African Grade 5 dataset.

These six responses were combined into a *Disorderly Behaviour during Mathematics Lessons Scale*[39]. There was a higher level of disorderly behaviour in South African mathematics classrooms when compared to other countries. Twenty-three percent of South African Grade 5 learners experienced disorderly behaviour in most lessons, compared to the international average of 14 percent.

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

In South Africa, we did not observe a statistically significant relationship between disorderly behaviour and achievement at the national level or in no-fee schools. However, there was a distinct relationship between disorderly behaviour and mathematics achievement in fee-paying schools.

Figure 53: Learners' experience of disorderly behaviour during mathematics lessons and achievement, by school fee-status



*Statistically significant achievement difference between categories.

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

39 See Mullis et al. (2020) for a description of the Disorderly Behaviour during Mathematics Lessons Scale (Page 290).

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 the sciences 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.

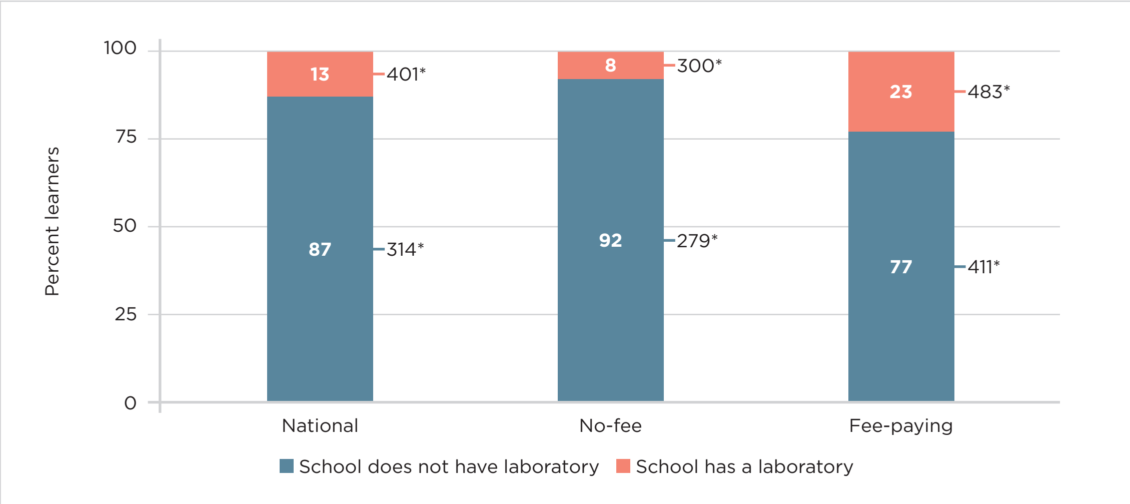
Schools with science laboratories

Using principals' responses, Figure 54 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.

Nationally, only 13 percent of Grade 5 learners attended schools that had a science laboratory. This contrasts with the National Education Infrastructure Management System 2020 report that showed that 20 percent of all schools in the country had a laboratory (DBE, 2020b). We were unable to corroborate with figures for secondary and primary schools.

When the TIMSS 2019 data were disaggregated by school fee-status, a quarter of the learners (23%) in fee-paying schools, compared to eight percent in no-fee schools, attended schools with a science laboratory. Learners in schools with a science laboratory achieved significantly higher science scores (401) than those that did not have a laboratory (314).

Figure 54: Percentage of learners attending a school with a science laboratory and science achievement, by school fee-status



* Statistically significant achievement difference between categories.

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

Instructional activities related to science investigation

Grade 5 science educators were asked how often they conducted certain instructional activities that emphasised science investigation (Table 34). According to the science educator reports there were a high number of science investigation activities conducted, with over 60 percent of the learners observing natural phenomena (68%), using evidence from experiments to support conclusions (63%) and designing or planning experiments (61%) in half or more science lessons. Only three in 10 learners frequently experienced fieldwork outside of the classroom.

Table 34: Percentage of learners taught by educators who reported doing the following during science lessons

Science investigation instructional activities	Percent learners reported science investigation activities in 'half the lessons or more'
Observe natural phenomena and describe what they see	68
Use evidence from experiments or investigations to support conclusions	63
Design or plan experiments or investigations	61
Watch me demonstrate an experiment or investigation	59
Interpret data from experiments or investigations	59
Conduct experiments or investigations	57
Present data from experiments or investigations	57
Do field work outside of class	29

Source: TIMSS 2019 South African Grade 5 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 the Grade 5 TIMSS data collected pre-Covid in 2018, we report on the access to digital technologies for learning in the home, school and mathematics and science classrooms.

Computers in the home

Just over half the learners (56%) reported having access to a computer (or tablet), and 37 percent reported having an Internet connection at home. These results may be over-reported (see Chapter 6).

Learners who reported access to digital technologies at home achieved significantly higher mathematics and science scores than learners without these resources (Table 35).

Table 35: Availability of a computer or tablet at home and achievement

Subject	National			
	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	56	391* (4.4)	44	357 (3.4)
Science	56	350* (6.1)	44	298 (4.5)

* Statistically significant difference between categories.

Source: TIMSS 2019 South African Grade 5 dataset.

Computer access in schools

The number of computers available for use in Grade 5 classes, as reported by principals, is shown in Table 36. Two-thirds (66%) of Grade 5 learners attended schools that had no access to computers and 20 percent of learners attended schools with more than 20 computers for their use. Learners in fee-paying schools were more likely to attend schools with computer access (26% in no-fee schools versus 49% in fee-paying schools).

Table 36: Percentage of learners with access to computers (including tablets) in Grade 5 classes

	Percent learners National	Percent learners No-fee	Percent learners Fee-paying
No computers	66	74	51
1 to 20 computers	14	14	15
21 or more computers	20	13	34

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

Computer access and use in classrooms

Mathematics and science educators responded to whether Grade 5 learners had access to computers to use in their mathematics and science lessons. About eight percent of learners attended schools that had access to computers for their mathematics and science lessons (Table 37). Learners who had access to computers for mathematics and science lessons achieved significantly higher mathematics and science scores than those without access.

Table 37: Percentage of learners with access to computers for Grade 5 mathematics and science lessons, and achievement

Subject	National			
	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	8	430* (15.2)	92	368 (3.8)
Science	7	422* (18.5)	93	319 (5.0)

* Significant achievement difference between categories.

Source: TIMSS 2019 South African Grade 9 dataset.

The following infographic provides a summary of what happened in Grade 5 classrooms in TIMSS 2019.

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

Classrooms

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 to complete the learning outcomes designed for that grade.

Educator characteristics

Grade 5 learners were predominantly taught by female mathematics and science educators. Sixty percent of mathematics and science learners were taught by educators with at least a Bachelors' degree and with the appropriate subject specialisation. Educators had on average 17- and 16-years' experience of teaching mathematics and science, respectively.

Resources: Class size

The average TIMSS Grade 5 class size was 44 learners, with class sizes ranging from six to 91 learners. The average class size in no-fee schools was 47 learners and in fee-paying schools it was 38 learners. Learners in classes with fewer than 40 learners achieved significantly higher mathematics and science scores than learners in classes with more than 40 learners.

Workbooks

Ninety-three percent of mathematics learners and 71 percent of science learners reported that they had access to their own or a shared workbook. Learners with their own mathematics and science workbooks achieved higher scores than those who shared or did not have a workbook.

Classroom instructional practices

On average, 70 percent of mathematics learners and 65 percent of science learners reported that their educators provided high clarity of instruction. There was a positive association between instructional clarity, and mathematics and science achievement.

Science investigations and experiments

According to principals, 13 percent of learners attended schools with a science laboratory. The availability of a science laboratory can serve as a proxy for resources in a school, and learners in schools with a laboratory achieved higher mathematics and science scores than learners in schools without a laboratory.

Computers in education and instruction

Two-thirds of Grade 5 learners (three-quarters in no-fee schools and half in fee-paying schools) attended schools with no access to computers, while 20 percent of learners attended schools with more than 20 computers for their use (13% of learners in no fee schools and 34% of learners in fee-paying schools). According to educators, only eight percent of mathematics learners and seven percent of science learners had access to computers for use in their mathematics and science lessons, respectively.

Section F 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 learners' performance in mathematics and science, showing how achievement varied by the type of school learners attended, the households they grew up in, and the availability of resources in both settings; and providing examples of what goes on in each context.

These characteristics – school infrastructure, school 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 their relationship with achievement reflects how those factors operate together. To get a better understanding of which influences have the strongest association with achievement and, therefore, which potential policy levers might yield the greatest achievement gains, we need to consider how these different factors operate together.

This chapter presents a series of bivariate and multivariate analyses (refer to Reader's Guide) to explore the relationships between key characteristics of where learners live and learn and their mathematics achievement, and how those relationships change when factors are considered together, and to identify the strongest associations with Grade 5 mathematics performance.

While we have used mathematics achievement as the outcome variable in this analysis, the results from this analysis talk to the quality of education and educational outcomes in the education system.

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 individual, family, early learning experiences 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 for the Intermediate Phase (Grade 5). In other words, when we consider all the measures that are associated with achievement simultaneously, which measures matter most? The analysis is presented in three sets of sequential regression models.

Bivariate associations

For completeness of building the model, we summarise the bivariate analyses presented in the previous chapters. The first set of regressions summarise the bivariate 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.

The regression results given here are shown in terms of the levels[40] of each predictor variable as already defined – e.g. school quintile 1 to 5; 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 statistically significant.

Grouped multivariate associations

The second set of analyses considers groups of characteristics, for example individual-level characteristics, indicators of household SES, and 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 individual variable's association with achievement will likely decrease, but this 'grouped' relationship effect will better reflect the actual context of the learner experiences. For example, learners with individual access to workbooks 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.

40 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.

Full multivariate model

The final analysis presents a single regression model with all influences on achievement considered together to identify the factors most associated with achievement. This last step in our multivariate approach attempts to fully capture the day-to-day lived experience of the learner, and the joint impact of the most important 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 workbooks, mathematics-specific teaching aids – as well as the school's 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.[41] The package also allows for analyses of datasets with plausible values (multiple 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.

In this section we did not include the number of observations (N) for each variable included in this model. This is reported in the previous chapters.

9.2. BIVARIATE ASSOCIATIONS

The following tables report the results from a series of bivariate regressions between mathematics achievement and measures of the learner characteristics, features of the home environment and the school they attend, shown to significantly correlate with achievement in the previous chapters. The coefficients show the basic association between each individual variable and attainment in mathematics without including any other measures in the model. The R-squared value is a statistical measure that represents the proportion of the variance for a dependent variable (mathematics achievement in this case) that is explained by an independent variable. Variables of interest are grouped into broad, context-based areas.

School quintile rank

Table 38 shows the basic association between school quintile and mathematics achievement and the coefficient (i.e. the average increase in TIMSS mathematics points for learners in each school quintile when compared to those in Quintile 1 (Q1). These coefficients are the same mean differences in learner scores between the school quintile shown in Chapter 2 which report that, on average, learners in Q2 schools scored an extra six points compared to those in Q1 schools (337 versus 331), those in Q3 schools an additional 22 points (354 versus 331) when compared to those in Q1, and so on.

In this bivariate model of influences on achievement, it is evident that the relationship between the school quintile rank and mathematics is very strong, with the average increase for learners in Q5 schools being around 155 points higher than in Q1 schools.

The school quintile characteristic accounts for 30 percent of variance in Grade 5 mathematics.

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

Table 38: Bivariate associations between school quintile and TIMSS mathematics achievement

School Quintile	Coeff.	SE	Sig.	R-squared
Quintile: (Ref = Q1)				
Q2	6	(6.9)		
Q3	22	(6.8)	**	
Q4	58	(8.0)	***	
Q5	155	(8.3)	***	
Independent	132	(14.4)	***	0.30

Source: Authors' own calculations from South African TIMSS 2019 Grade 5 dataset.

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

Household characteristics and school readiness

The home environment is another very important developmental context for children, both in terms of household characteristics, such as SES and the availability of resources, but also with respect to the provision of a cognitively stimulating environment and the fostering of early academic skills (Table 39).

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 85 points lower. Parents' own level of education, measured here in terms of how complex parents find their child's schoolwork, was also significantly associated with mathematics achievement. Compared to those whose parents never found schoolwork too complex to help with, learners whose parents sometimes struggled scored an average of 37 points lower, and those whose parents frequently struggled scored, on average, 67 points less.

Engaging young children in early educational activities frequently was positively associated with achievement in mathematics. Learners whose parents reported only sometimes or never spending time on literacy and numeracy activities before starting school scored, on average, 40 points lower than those whose parents regularly engaged them in such activities. In terms of their level of school readiness, learners whose parents reported their child's literacy and numeracy skills were 'very good' at entry to school scored an average of 45 points higher than those whose skills were rated as 'moderate', and 73 points more than those whose skills were rated as 'poor'.

For preschool attendance, there was no significant difference between learners who did not attend preschool and those who attended for one year or less, but learners who attended for two years or more scored, on average, 18 points more than those who never attended an early year educational setting.

Of the variables considered here, household SES accounted for the highest proportion of variance in Grade 5 mathematics (11%), with preschool attendance – where only eight percent of learners did not attend pre-school – accounting for the lowest variance (1%).

Table 39: Bivariate associations between household characteristics and school readiness and achievement

Household Characteristics and School Readiness	Coeff.	SE	Sig.	R-squared
Household SES indicator: (Ref = High)				
Middle	-63	(5.2)	***	
Low	-85	(5.8)	***	0.11
Schoolwork is too complex for parents: (Ref = Never)				
Sometimes	-37	(4.0)	***	
Frequently	-67	(4.5)	***	0.05
Frequency parents engage in literacy and numeracy activities before school: (Ref = Frequently)				
Sometimes / Never	-40	(4.2)	***	0.03
School readiness: Literacy and numeracy skills at entry to school (Ref = Very good)				
Moderate	-45	(3.5)	***	
Poor	-73	(5.7)	***	0.06
Preschool attendance: (Ref = None)				
1 year or less	-10	(6.1)		
2 years or more	18	(7.4)	*	0.01

Source: Authors' own calculations from South African TIMSS 2019 Grade 5 dataset.

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

Individual-level characteristics

Girls scored an average of 20 points more than boys. Learners who were overage for Grade 5 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 also strongly related to performance (Table 40).

While significantly associated with achievement in mathematics, at least at the basic bivariate level, learners' gender accounted for a very small proportion of the variation in Grade 5 mathematics achievement. Age and language proficiency each explained eight percent of variation in learners' achievements.

Table 40: Bivariate associations between individual characteristics and achievement

Individual-level Characteristics	Coeff.	SE	Sig.	R-squared
Girl	20	(2.9)	***	0.01
Age bands: (Ref = Correct Age)				
Overage by less than 12 months	-51	(3.3)	***	
Overage by more than 12 months	-89	(4.5)	***	0.08
Language proficiency: Speak lang. of test at home (Ref = Frequently)				
Sometimes	-38	(5.2)	***	
Never	-93	(7.2)	***	0.08

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

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

Learners' educational attitudes

Learners who were very confident in their own abilities in mathematics, scored on average 85 points higher than those who were somewhat confident, and 117 points more than those who reported having no confidence in their mathematical skills in Grade 5. Liking of the subject was also associated with doing well in it: those who did not like learning mathematics scored, on average, 81 points less than those who very much liked learning it, while learners who reported somewhat liking it scored 70 points lower (Table 41).

Interestingly, both indicators of learner attitudes towards mathematics individually accounted for quite a high proportion of the overall achievement variance in Grade 5 TIMSS achievement: 15 percent and 13 percent, respectively.

Table 41: Bivariate associations between learner attitudes at school and achievement

Learner Attitudes	Coeff.	SE	Sig.	R-squared
Learner confident in mathematics: (Ref = Very confident)				
Somewhat confident	-85	(4.8)	***	
Not confident	-117	(5.3)	***	0.15
Learner likes mathematics: (Ref = Really likes)				
Somewhat likes	-70	(3.1)	***	
Does not like	-81	(4.8)	***	0.13

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 dataset.

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

Educator and classroom characteristics

Individual access to a workbook was found to be an important predictor of achievement: Learners who shared or had no access to their own workbook (17%) scored, on average, 60 points lower than those who did have their own workbook. Where instruction in mathematics was affected by resource shortages, the average difference in TIMSS performance between learners who were and were not affected was 85 points. Learners in smaller classes scored, on average, 48 points more than those in larger teaching groups (Table 42).

Interestingly, while educator qualifications – having at least a Bachelor's degree – was not significantly associated with achievement in Grade 5 TIMSS mathematics, the clarity of instruction was. Where instructional clarity was moderate compared to high, learners scored an average of 52 points less and where it was low, the difference was 89 points. Furthermore, of the educator and classroom characteristics considered, instructional clarity was the largest contributor (9%) to the variation in learner achievement.

Table 42: Bivariate associations between educator and classroom characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.	R-squared
Learner does not have own workbook	-60	(4.2)	***	0.05
Instruction affected by shortage of maths resources: (Ref = Not affected)				
Affected	-85	(23.3)	***	0.05
Class size: Over 40 learners (Ref = Classes under 40 learners)	-48	(7.9)	***	0.06
Teacher qualification: (Ref: No degree qualification)				
Bachelors or above	11	(10.2)		0.00
Instructional Clarity in mathematics lessons is high:				
Moderate Clarity	-52	(3.7)	***	
Low Clarity	-89	(3.8)	***	0.09
Presence of disorderly behaviour during lessons: (Ref = Few / None)				
Some/Most Lessons	-12	(7.6)		0.00

Source: Authors' own calculations from TIMSS 2019 South African Grade 5 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 56 points, and by 95 points for those attending schools in remote rural areas. The spatial location of the school was the largest single contributing variable (16%) to the overall variation in Grade 5 mathematics achievement in this block (Table 43).

The number of computers in a school is one example of the level of resources available and this was positively associated with learner achievement in Grade 5 TIMSS mathematics. Learners in schools with between 1 and 20 computers scored an average of 31 points more than those in schools with none, doubling to an additional 65 points where availability was above 20 computers. Whether schools have a science laboratory is another signal of overall school-level resourcing. In the Grade 5 TIMSS sample, 13 percent of learners attended schools that had a science laboratory and attending a school that had one was associated with, on average, an additional 62 points in mathematics.

Learners who were regularly bullied performed worse in mathematics, with those experiencing monthly bullying scoring an average of 47 points less than those who were never or almost never bullied, rising to a difference of 91 points when the bullying occurred weekly. Experiences of bullying alone accounted for 11 percent of the variation in learner achievement.

In terms of indicators of the overall school climate, learners in schools with a strong emphasis on academic success scored, on average, 43 points higher than those in schools where the academic emphasis was described as medium. Learners in schools where the principals reported hardly any problems with discipline achieved a 27-point higher score than those where such behaviour was reported as problematic; and learners in the safest schools scored, on average, 21 points more than those in less than safe and orderly schools.

Table 43: Bivariate associations between principal and school-level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.	R-squared
Spatial location of school: (Ref = Big and medium cities and suburbs)				
Small towns or villages	-56	(9.4)	***	
Remote rural	-95	(7.0)	***	0.16
Number of computers in the School: (Ref = 0)				
1 to 20	31	(12.6)	*	
Over 20	65	(11.7)	***	0.07
School has a science laboratory	62	(16.5)	***	0.04
Learner is bullied: (Ref = Never or Almost Never)				
About Monthly	-47	(4.6)	***	
About Weekly	-91	(6.0)	***	0.11
School's emphasis placed on academic success: (Ref = Strong Emphasis)				
Medium	-43	(8.4)	***	0.04
School discipline problems: (Ref = Hardly any)				
Minor/Moderate Problems	-27	(13.5)	*	0.01
Safe and orderly schools: (Ref = Very safe and orderly)				
Less than safe and orderly	-21	(9.9)	*	0.01

Source: Authors' own calculations from South African TIMSS 2019 Grade 5 dataset.

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

9.3. GROUPED MULTIVARIATE ASSOCIATIONS

The next step in our analysis to understand the factors affecting mathematics achievement was to examine the nature of the associations when multiple factors are considered jointly. In other words, when similar types of variables – characteristics of the household and home learning environment, for example – are included together, do they all still matter? Or do the correlations between the different factors – engagement in early educational activities and levels of school readiness – mean that some factors matter more than others?

Household characteristics and school readiness

When considered jointly, all but one of the five measures of the home environment used in our model continued to be associated with Grade 5 achievement in mathematics (Table 44). Only preschool attendance – which in the bivariate associations in Table 39 was only significant for those attending for two years or more – was no longer significant in the grouped association model. The size of the association was reduced by more than half, falling from 18 to 8 points in mathematics achievement, reflecting its correlation with school readiness, weaker association with achievement and smaller relative power on its own in explaining variations in overall mathematics achievement.

The size of all the other associations did fall slightly when taken together, indicating some degree of correlation between each of the variables (e.g. learners whose parents engaged more frequently in early educational activities at home started school with stronger literacy and numeracy skills), but they still remained strong predictors of attainment and together accounted for 21 percent of the variance in Grade 5 TIMSS mathematics achievement.

Table 44: Grouped multivariate associations between characteristics of the home and school readiness and achievement

Household Characteristics and School Readiness	Coeff.	SE	Sig.	R-squared
Household SES indicator: (Ref = High)				
Middle	-57	(5.4)	***	
Low	-77	(6.0)	***	
Schoolwork is too complex for parents: (Ref = Never)				
Sometimes	-27	(3.9)	***	
Frequently	-50	(5.1)	***	
Frequency parents engage in literacy and numeracy activities before school: (Ref = Frequently)				
Sometimes/Never	-23	(3.7)	***	
School readiness: Literacy and numeracy skills at entry to school (Ref = Very good)				
Moderate	-31	(3.8)	***	
Poor	-51	(6.9)	***	
Preschool attendance: (Ref = None)				
1 year or less	-9	(5.6)		
2 years or more	8	(6.7)		0.21

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

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

Individual-level characteristics

When learners' gender, age and language proficiency were considered jointly, each variable continued to be strongly and significantly associated with mathematics achievement. While the coefficient between learners' gender and achievement was halved, even when age and language were taken into account, girls still scored a significant average of 9 points more than boys (Table 45).

Taking these three individual-level characteristics together did not reduce the strength of the associations between age or language proficiency and mathematics achievement, suggesting that these learner characteristics are not themselves highly correlated. Together, these characteristics accounted for 16 percent of the variation in Grade 5 mathematics achievement.

Table 45: Grouped multivariate associations between individual characteristics and achievement

Individual-level Characteristics	Coeff.	SE	Sig.	R-squared
Girl	9	(2.9)	**	
Age bands: (Ref = Correct age)				
Overage by less than 12 months	-47	(3.2)	***	
Overage by more than 12 months	-81	(4.4)	***	
Language proficiency: Speak lang. of test at home (Ref = Frequently)				
Sometimes	-39	(5.1)	***	
Never	-85	(6.7)	***	0.16

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10

Learners' educational attitudes

Learner confidence in mathematics and liking of the subject both independently predicted Grade 5 TIMSS achievement. When considered simultaneously, their associations were slightly reduced, but both attitudinal factors were still strongly associated with Grade 5 performance. Moreover, these two variables alone accounted for 20 percent of the overall variation in achievement, a similar percentage to the five indicators of household SES and home learning environment (Table 46).

Table 46: Grouped multivariate associations between learner attitudes and experiences at school and achievement

Learner Attitudes and Experiences at School	Coeff.	SE	Sig.	R-squared
Learner confident in mathematics: (Ref = Very confident)				
Somewhat confident	-65	(4.6)	***	
Not confident	-85	(5.7)	***	
Learner likes mathematics: (Ref = Really likes)				
Somewhat likes	-46	(3.2)	***	
Does not like	-54	(5.0)	***	0.20

Source: Authors own calculations from TIMSS 2019 Grade 5 dataset.

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

Educator and classroom characteristics

When the educator and classroom characteristics were considered jointly, all of the significant bivariate associations held: educator qualifications and the presence of disorderly behaviour remained non-significant but were kept in the model to compare how their associations might have changed once features of the classroom were taken altogether (Table 47).

Again, with the inclusion of all variables, the strength of some of these associations did fall slightly, reflecting collinearity (inter-relationships) between the different features of the classroom context. For example, in the bivariate model, learners with individual access to a workbook scored, on average, 60 points higher than those without. Once we also considered whether or not instruction in the classroom was affected by a shortage of mathematics resources (of which access to workbooks is likely to be a part) this average 'gain' fell to 42 points. Despite the reduction in the size of the association through its relationship with resources, both factors continued to strongly and independently be associated with Grade 5 TIMSS mathematics achievement.

In this grouped model, smaller class sizes continued to be significantly associated with mathematics achievement. So too, instructional clarity remained a particularly salient predictor of attainment, and together the characteristics of the educator and classroom accounted for 20 percent of the variation in mathematics achievement.

Table 47: Grouped multivariate associations between classroom and educator characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.	R-squared
Learner does not have own workbook	-42	(4.0)	***	
Instruction affected by shortage of maths resources: (Ref = Not affected)				
Affected	-66	(19.2)	***	
Class size: Over 40 learners (Ref = Classes under 40 learners)	-43	(7.9)	***	
Teacher qualification: (Ref = No degree qualification)				
Bachelors or above	12	(8.9)		
Instructional Clarity in mathematics lessons is high:				
Moderate Clarity	-41	(3.8)	***	
Low Clarity	-78	(4.5)	***	
Presence of disorderly behaviour during lessons: (Ref = Few / None)				
Some/Most Lessons	-2	(5.7)		0.20

Source: Authors own calculations from TIMSS 2019 Grade 5 dataset.

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

Principal and school-level characteristics

In the joint model of school-level factors, the majority of the significant bivariate relationships remained: the spatial location of schools, number of computers, presence of a science laboratory, learner experience of bullying, and school emphasis on academic success all had strong and significant associations with mathematics achievement.

Once considered jointly with other measures of the school context, however, the relationships of both discipline problems and school safety with learner achievement were reduced considerably, becoming non-significant. As noted above, this reflects collinearity between the features of the school environment and which variables are more strongly associated with achievement.

For example, experiences of bullying were particularly strongly associated with achievement in mathematics, more so than school discipline or safety in the bivariate model, but it is likely that in schools where bullying is more prevalent, discipline problems are also higher and, at the same time, schools are deemed less safe. These features of the school environment operate together, rather than independently. The bivariate significant association between school discipline and achievement or school safety and achievement, reflect that both these school climate characteristics were higher where bullying was greater and so once the level of bullying was considered, these other characteristics were no longer independently associated with achievement.

Principal and school-level characteristics accounted for nearly a third (32%) of the variation in learner achievement.

Table 48: Grouped multivariate associations between principal and school-level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.	R-squared
Spatial location of school: (Ref = Big and medium cities and suburbs)				
Small towns or villages	-50	(9.3)	***	
Remote rural	-77	(7.1)	***	
Number of computers in the School: (Ref = 0)				
1 to 20	19	(7.7)	*	
Over 20	39	(9.1)	***	
School has a science laboratory	36	(12.8)	**	
Learner is bullied: (Ref = Never or Almost Never)				
About Monthly	-33	(3.3)	***	
About Weekly	-68	(4.2)	***	
School's emphasis placed on academic success: (Ref = Strong Emphasis)				
Medium	-25	(6.8)	***	
School discipline problems: (Ref = Hardly any)				
Minor/Moderate problems	-5	(8.7)		
Safe and orderly schools: (Ref = Very safe and orderly)				
Less than safe and orderly	-4	(6.6)		0.32

Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

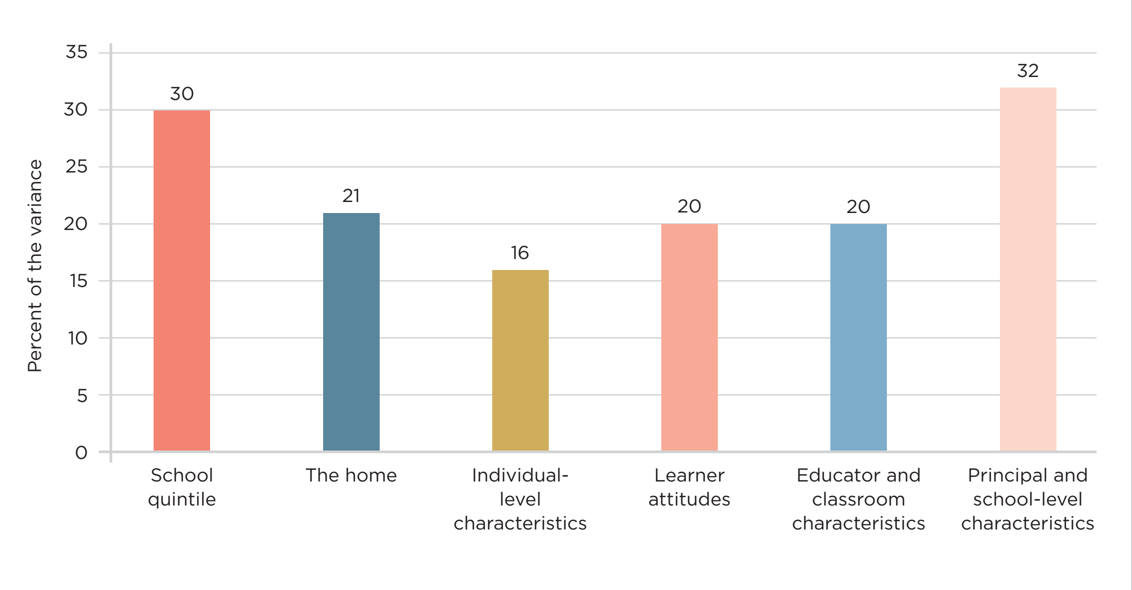
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10

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

Each of the grouped associations (Tables 44 to 48) were 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 the individual, home and school-level characteristics are able to explain (Figure 55).

As noted earlier, the quintile rank of a school was strongly and significantly associated with mathematics achievement, and alone accounted for 30 percent of the variation in learner performance. The features of the home environment (both SES and school readiness) accounted for 21 percent of the variation in Grade 5 mathematics achievement, while individual-level characteristics (gender, age, language proficiency) explained 16 percent of the variation. Learners' educational attitudes, and educator and classroom characteristics, each accounted for 20 percent of the variance. This comparison is particularly noteworthy since the attitudinal block of predictors comprised just two variables – confident in and liking of mathematics – yet was larger in size than the individual-level characteristics and similar to the collective association of household factors. Finally, the principal and school-level characteristics, the highest proportion, accounted for 32 percent of variation in attainment.

Figure 55: Variance in TIMSS mathematics achievement accounted for by different blocks of covariates



Source: Authors' own calculations from TIMSS 2019 Grade 5 dataset.

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

It is important to note, however, that in the same way that indicators within the different sets of covariates are related to each other, so too are the different blocks themselves: learners from higher SES homes are more likely to attend higher quintile ranked schools and be proficient in the language of the test; instructional clarity is likely to be higher in smaller classrooms where greater emphasis is placed on academic success and discipline problems are less prevalent. The proportion of variance accounted for by each set of the covariates cannot be thought of as simply additive, but rather an indication of the relative size of each contributing area to predicting achievement. To understand the total variation that all these factors are able to explain in relation to Grade 5 TIMSS achievement in mathematics and identify the strongest predictors of performance, we need to consider how they operate when they are all considered simultaneously.

9.5. FULL MULTIVARIATE MODEL

The final step in our analysis was to enter all the factors associated with achievement into the model jointly and explore which factors remained significant when they were all considered simultaneously, as well as the size and strength of significant associations.

Table 49 reports the coefficients (i.e. the size of each association) for a single regression model. The model used is deliberately simple, focusing on indicators shown in the preceding chapter (and earlier tables) to significantly correlate with achievement as well as tangible characteristics of the learner's environment most likely to be amenable to change.

In the full multivariate model with all factors considered, only learners in Q5 and independent schools scored significantly higher than those in Q1 schools, indicating that individual, home, classroom and other school-level factors were adjusted for; there was no difference in the average performance of learners in Q1, Q2, Q3 or Q4 schools. Learners in Q5 schools scored, on average, 69 points higher, and those in independent schools scored 65 points higher than those in Q1 schools. The quintile rank of the school encompasses the characteristics of school resources and environment.

Over and above the school quintile rank, characteristics of the home continued to have strong and significant associations with Grade 5 mathematics achievement, though the size of associations decreased considerably. For example, in the grouped associations reported in Table 44, learners from middle SES homes scored, on average, 57 points lower than those from high SES households. However, when the model takes into account which schools learners attended, they scored just 10 points lower. Once all other factors are adjusted for, there was no significant difference in achievement between learners from high and low SES households, reflecting the high concentration of low SES learners in lower quintile schools: the school quintile rank largely mediated the relationship between family-level SES and achievement for those in the lowest SES group.

Interestingly, our proxy measure for parents' education – schoolwork is too complex – remained a highly significant factor of mathematics achievement, with learners of parents who never struggled with the complexity of homework scoring 24 points more than those who struggled frequently. Parents' early educational engagement with their children as well as their assessment of their school readiness mattered. Exposure to early learning activities also remained marginally significant in the full model, while learners assessed as being school ready scored 22 points more than those who were not school ready. In this model, pre-school attendance did not yield significant differences, probably because only eight percent of learners did not attend pre-school.

For the individual-level factors, the relationship between being a girl and achievement in mathematics was further reduced, becoming non-significant. Overage learners and those less proficient in the language of learning and teaching performed less well than those of the correct age, and those who frequently spoke the language of the test at home.

It is noteworthy that even in this comprehensive model of attainment, learner confidence in and liking of mathematics continued to be significantly associated with attainment. Over and above the school attended, the family circumstances, age, language proficiency, classroom resources, instructional practices and school climate, learners who were very confident in their own mathematical ability scored 33 points higher than those who were somewhat confident and 53 points more than those who were not confident.

Within the classroom, individual access to a workbook continued to make a significant difference to achievement outcomes. Learners without access to a workbook or who shared a workbook scored, on average, 16 points less than those who had their own workbook. Resource shortages specific to mathematics remained marginally significant in the final model, and learners in smaller classes scored an average of 13 points more than those in classes with more than 40 learners.

Of note was the role instructional clarity played in predicting Grade 5 mathematics achievement. After adjusting for all other factors in the model, including classroom resources and school climate, learners in classrooms where the instructional clarity was rated high scored 33 points higher than those experiencing low levels of instructional clarity.

Learners in remote rural schools scored an average of 27 points less than those in schools in cities and suburbs. Learners in better resourced schools, with more computers and presence of a science laboratory, attained higher scores. The climate of the school mattered for learner achievement. Bullying's association with mathematics achievement remained strongly negative, with those experiencing weekly bullying scoring around 29 points less than those who rarely experienced bullying. Academically focused school environments were positively associated with achievement, with learners in schools that placed a strong emphasis on academic success scoring 24 points more than those who placed a medium emphasis.

When taken together, these characteristics of the learner, their home and school environments were able to explain 59 percent of the overall variation in Grade 5 mathematics achievement.

Table 49: Multivariate associations between all factors and achievement

	Coeff.	SE	Sig.
School Quintile			
Quintile: (Ref = Q1)			
Q2	-1	(6.9)	
Q3	2	(8.4)	
Q4	13	(9.7)	
Q5	69	(10.9)	***
Independent	65	(14.5)	***
The Home			
Household SES indicator: (Ref = High)			
Middle	-10	(3.5)	**
Low	-7	(4.1)	
Schoolwork is too complex for parents: (Ref = Never)			
Sometimes	-11	(3.0)	***
Frequently	-24	(5.7)	***
Frequency parents engage in literacy and numeracy activities before school: (Ref = Frequently)			
Sometimes/Never	-7	(3.6)	†
School readiness: Literacy and numeracy skills at entry to school (Ref = Very good)			
Moderate	-16	(3.6)	***
Poor	-22	(6.7)	***
Preschool attendance: (Ref = None)			
1 year or less	-5	(4.6)	
2 years or more	-2	(5.1)	
Individual-level Characteristics			
Girl	3	(3.3)	
Age bands: (Ref = Correct age)			
Overage by less than 12 months	-19	(4.0)	***
Overage by more than 12 months	-31	(6.1)	***
Language proficiency: Speak lang. of test at home (Ref = Frequently)			
Sometimes	-12	(3.8)	**
Never	-35	(6.0)	***
Learner Attitudes and Experiences at School			
Learner confident in mathematics: (Ref = Very confident)			
Somewhat confident	-33	(3.5)	***
Not confident	-53	(4.2)	***
Learner likes mathematics: (Ref = Really likes)			
Somewhat likes	-22	(3.3)	***
Does not like	-18	(5.4)	***

	Coeff.	SE	Sig.
Educator and Classroom Characteristics			
Learner does not have own workbook	-16	(3.9)	***
Instruction affected by shortage of maths resources: (Ref = Not affected)			
Affected	-16	(8.3)	†
Class size: Over 40 learners (Ref = Classes under 40 learners)	-13	(4.9)	**
Teacher qualification: (Ref = No degree qualification)			
Bachelors or above	-6	(4.9)	
Instructional Clarity in mathematics lessons is high:			
Moderate Clarity	-8	(4.0)	*
Low Clarity	-33	(5.2)	***
Presence of disorderly behaviour during lessons: (Ref = Few / None)			
Some/ Most Lessons	7	(4.4)	
Principal and School-level Characteristics			
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages	-8	(6.9)	
Remote rural	-27	(7.6)	***
Number of computers in the School: (Ref = 0)			
1 to 20	-1	(7.0)	
Over 20	16	(6.7)	*
School has a science laboratory	17	(6.2)	**
Learner is bullied: (Ref = Never or Almost Never)			
About monthly	-9	(3.0)	**
About weekly	-29	(3.5)	***
School's emphasis placed on academic success: (Ref = Strong Emphasis)			
Medium	-24	(5.5)	***
School discipline problems: (Ref = Hardly any)			
Minor / Moderate Problems	8	(6.6)	
Safe and orderly schools: (Ref = Very safe and orderly)			
Less than safe and orderly	2	(5.0)	
R-squared		**0.59**	

Source: Authors' own calculations from the South African TIMSS 2019 Grade 5 dataset.

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

9.6. FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

This chapter summarised the individual, home and school influences on Grade 5 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 bivariate associations and building up to a comprehensive, yet relatively parsimonious, model of the key factors associated with mathematics achievement. The aim was to highlight how certain relationships might change or weaken in size, when multiple factors were considered together, to demonstrate the importance of examining the associations of characteristics jointly, and to identify the factors most related to mathematics achievement.

From the multivariate analysis, using a range of characteristics across individual, home and school contexts, a number of key findings emerged:

- In South Africa, an individual's circumstances at birth remain critical determinants of their life chances. The home SES and level of parental education contributed to home educational interactions, which then contributed to the readiness of children to enter schools.
- Schools have the capacity to positively improve educational outcomes. Principal and school-level characteristics accounted for nearly a third of variance in learner achievement, and educator and classroom factors accounted for 20 percent of the variance. While the home matters, schools can and must make a difference.
- Ninety-two percent of learners attended pre-schools, including Grade R. The multivariate association did not pick up a significant relationship, probably because of the very small percentage who did not attend Grade R.
- Because of the collinearity between quintile rank variable and the other environmental variables in the model, there was no significant difference in the average mathematics performance for learners in Quntile1, 2, 3 or 4 schools.
- There were significant achievement differences between schools located in urban areas and those in remote rural areas. With half the learners in no-fee schools located in rural areas this finding has policy implications.
- The school quintile rank mediated the relationship between household SES and learner achievement for those in the lower quintile ranked schools. That is, once we accounted for the school a learner attended, family-level SES had a much smaller association with Grade 5 mathematics achievement. This likely reflects the higher concentration of learners from low SES households in lower quintile schools. This is not the case for learners from middle SES households who, once school quintile was controlled for, continued to do worse than those from high SES homes, probably because they were more evenly distributed across all school quintiles.
- Resources in school matter. Individual access to workbooks was a key predictor of achievement. Greater access to resources specific to the teaching of mathematics, as well as access to assets like science laboratories, were all independently associated with learner achievement. As part of the resource infrastructure of a school, decreasing class sizes is an important piece of the resourcing puzzle and learners should be taught in smaller classes.
- Schools need to be safe places, not just for learners but also for educators. 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.
- Schools that encourage a climate that places an emphasis on academic success were more successful and learners responded well to lessons with high instructional clarity, attaining higher achievement scores.
- This analysis confirms previous studies that found that learners who frequently speak the language of instruction, are regularly exposed to it, and use the language outside of school, are at an advantage.
- The multivariate analysis also points to the fact that overage learners achieved significantly lower scores than learners who were the correct age for the grade.
- While there is significant gender achievement difference favouring girls in the bivariate model, once other variables have been accounted for in the multivariate model this advantage drops away.
- Recognising the bidirectional relationship between learner attitudes and achievement, learner confident in their abilities, over and above the other factors included in the model, was an important predictor of achievement. Learners' own academic beliefs are key factors related to achievement.

In the final part of this report, Section F, we present a set of key findings and implications for the South African education system from the 2019 Grade 5 TIMSS assessment.

SECTION G
RESULTS AND IMPLICATIONS

This TIMSS 2019 Grade 5 report has provided an insight into South African mathematics and science achievement in the Intermediate Phase of the schooling system.

With this report, we have retold the predictable South African 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 determine the schools one attends and life trajectory. Education and schooling are the responsibility of both the state and society, and educational outcomes are dependent on both in-school and out-of-school factors. But schools have the capacity to positively change educational outcomes. In this report we have identified various factors within schools that could promote improved learner achievement.

We analysed the self-reported data from Grade 5 learners, educators, principals, and parents to identify factors associated with mathematics and science achievement. This section brings together the main results from the descriptive, inferential, and multivariate analyses, and furthermore provides policy recommendations for improving educational quality and outcomes. We firstly highlight key results from the study, and then discuss relevant recommendations for improving educational achievement in South Africa.

Having administered TIMSS Numeracy for the first time at Grade 5 in 2015, the data from TIMSS 2019 provides a methodologically sound measure to estimate the trend in mathematics performance, as well as to set a baseline for achievement in science. This will contribute to monitoring progress in the Intermediate Phase of primary education in the country.

CHAPTER TEN

RESULTS, IMPLICATIONS AND RECOMMENDATIONS FROM GRADE 5 TIMSS 2019

A. RESULTS FROM TIMSS 2019

Grade 5 mathematics and science performance

1. **Mathematics and science achievement:** Of the 58 countries that participated in TIMSS 2019, South Africa was one of the lower performers in both mathematics and science, with average national scale scores of 374 (3.6) and 324 (4.9), respectively.

   There was very high variation in the mathematics and science scores. The achievement difference (distribution inequality) between the 5th and 95th percentiles was 330 points for mathematics and a higher 434 points for science. This suggests that science learners experienced additional difficulties in accessing the science content (See Section B Point 4 of this chapter for details).

2. **Mathematics and science ability:** Thirty-seven percent of Grade 5 South African mathematics learners and 28 percent of science learners had acquired basic mathematical and science knowledge respectively.

   It is noteworthy that five percent of mathematics learners and six percent of science learners reached the higher international achievement benchmarks, meaning that they were able to apply their knowledge to solve more complex problems.

3. **Achievement trends:** The TIMSS 2015 and 2019 cycles provided a trend measure for mathematics achievement in the Intermediate Phase. The difference in the average mathematics scale score of 376 (3.5) in TIMSS 2015 and 374 (4.7) in TIMSS 2019 was not statistically significant. The percentage of learners who demonstrated that they had acquired basic mathematical knowledge was 39 percent in 2015 and 37 percent in 2019.

   The Grade 5 trend results are perplexing as the TIMSS mathematics scores increased at Grade 9 in the same period. While mathematics achievement remained the same on most indicators between 2015 and 2019, the achievement score was significantly lower for the Mpumalanga province in 2019.

4. **Achievement and ability gaps in no-fee and fee-paying schools:** Achievement in South Africa continues to be unequal, with significant achievement differences between learners attending no-fee and fee-paying schools.

   The achievement gap between learners attending fee-paying and no-fee schools was 109 points for mathematics and 150 points for science. Twenty-four percent of mathematics learners and 14 percent of science learners in no-fee schools, compared with 68 percent of mathematics learners and 60 percent of science learners in fee-paying schools had acquired basic mathematics and science knowledge.

5. **Provincial achievement gaps:** The highest performing provinces for mathematics and science were the Western Cape and Gauteng provinces. The lowest performing provinces were Mpumalanga and Limpopo. The provincial achievement gap (difference between the highest and lowest performing provinces) was 110 points for mathematics and a higher 141 points for science.

Curriculum

6. In relative terms, science achievement was lower than mathematics achievement. Fewer Grade 5 learners demonstrated that they had acquired scientific knowledge (28%) than mathematical knowledge (37%).

   The South African curriculum prescribes that the numeracy learning area is taught from Grade 1, while the Natural Science and Technology subject is introduced in Grade 4.

   For science, although there was an 80 percent match between the TIMSS and the South African Curriculum and Policy Assessment Statement (CAPS), learner performance was low. There are multiple factors that affected science achievement.

7. TIMSS is not a simple assessment. To answer the TIMSS assessment successfully, 60 percent of the Grade 5 items were classified as requiring learners to use the higher cognitive skills of application and reasoning. The South African assessment framework places a greater focus on the skills of knowing and solving routine problems and there is limited emphasis on applying and reasoning skills[42].

   Learners performed relatively better in items that required them to select a response (multiple choice question) than in items where they had to write a response (constructed response). The average percent correct for constructed response less difficult mathematics items was 36 percent compared to 18 percent for science. On average, learners had difficulty answering items that required them to coherently write descriptions or explanations.

Individual characteristics and home environments

Individual characteristics

8. On average boys enrolled in the 5th Grade were 0.3 years older than girls, and boys scored a significantly lower 20 points for mathematics and 21 points for science, than girls. Understanding gender differences is complex, and when measured with other variables (e.g. age) the significant gender differences diminish, suggesting that there are interaction effects between the variables.

   We concur with the Department of Basic Education's (DBE's) concern regarding the poor performance of boys. This disadvantage for boys starts early and widens as they progress through the education system (see TIMSS results at Grade 9, Reddy et al., 2022).

9. Nationally, a quarter (27%) of Grade 5 learners (30 percent in no-fee schools and 19 percent in fee-paying schools) were overage. Learners may have been overage due to starting school late, dropping in and out of school, or repeating a grade. Learners who were the correct age for Grade 5 achieved significantly higher mathematics and science scores than those who were overage.

10. One-third (35%) of Grade 5 learners frequently spoke the language of the test (either English or Afrikaans) at home and therefore had better linguistic access to the TIMSS assessments. The picture differed by school fee-status, with a quarter of learners in no-fee schools and half the learners in fee-paying schools frequently speaking the language of the test at home. Learners who frequently spoke the language of the test at home achieved significantly higher achievement scores than learners who never spoke the language of the test at home.

11. Learner attitudes towards the subjects explained a sizeable variation (20%) in achievement scores. There was a significant association between learners' confidence in their mathematics and science abilities and achievement, as well as between the extent to which they liked these subjects and achievement.

Home environment and early learning activities

12. The availability of assets and educational resources in the home was significantly associated with mathematics and science achievement. About a quarter of learners came from homes categorised as high socioeconomic status (SES), a quarter from medium SES homes and half from low SES homes. The household characteristics (assets, parental education, engaging children with literacy and numeracy activities) explained 21 percent of the mathematics 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.

13. Early numeracy and literacy development was significantly associated with learners' Grade 5 achievement in school mathematics and science. A quarter (28%) of South African parents or guardians, as compared to 42 percent internationally, often engaged with their children on literacy and numeracy tasks at a young age. Learners who were exposed to these engagements achieved significantly higher mathematics and science scores.

42 According to the CAPS documents, the mathematics assessment guidelines are: 25% knowing items, 45% routine problems, 20% complex procedures and 10% problem solving. For science, the guidelines are: 50% lower order questions, 35% middle order questions and 15% higher order questions.

Approximately half of the Grade 5 learners were rated as literacy ready by their parents when they entered school, and a quarter were rated as numerically ready. Learners who were reported as having a better foundation in literacy and numeracy skills outperformed learners with low foundational skills in the mathematics assessment.

14. Ninety-two percent of learners attended Grade R classes. While the bivariate analysis showed that learners who attended two years of pre-school achieved significantly higher scores than attending for one year or less, this relationship did not endure in the multivariate analysis, probably because of the interaction with other factors, or due to the small reference group (8%) the relationship disappeared.

School and classroom contexts

15. There was a high variation in learning outcomes among schools. The poverty rank of the school (quintile) a learner attended explained 30 percent of the achievement variance. There was a continuity of educational conditions from homes to schools. Two-thirds of learners in no-fee schools, compared with a quarter of learners in fee-paying schools, came from low SES households.

16. Because of the collinearity between the quintile rank variable and other environmental factors, we found there was no significant difference in achievement performance for learners in Quintile 1, 2, 3 and 4 schools. Learners who attended schools in remote areas experienced multiple disadvantages and they had significantly lower mathematics and science scores than learners in schools close to cities and towns. Half of the learners in no-fee schools attended schools in rural areas.

17. Most learners attended schools that were characterised by unsafe conditions, with discipline problems in the school and classroom, and learner bullying being widespread. Compared with other countries, South Africa experienced higher levels of reported disciplinary, safety and bullying problems. All three school climate factors were significantly associated with mathematics and science achievement. Learners who were in safer schools with hardly any discipline problems, and who hardly experienced any form of bullying, achieved significantly higher mathematics and science scores. There were significantly higher levels of bullying on all behaviour items in no-fee schools than in fee-paying schools.

18. Around 60 percent of learners were taught by mathematics and science educators who reported that they had, at least, a Bachelors' qualification. Two-thirds of mathematics learners and half of the science learners were taught by educators who reported a specialisation in the subject. Compared with other countries, South African educators reported attending the highest number of professional development courses.

19. Learners achieved higher achievement scores in classrooms where subject matter was presented with high instructional clarity. Similarly, learners in schools that placed a high emphasis on academic success achieved better learning outcomes.

20. The average TIMSS class size at the national level was 44 learners per class. When disaggregated by school fee-status, the average class size was 47 learners in no-fee schools compared to 38 learners in fee-paying schools. Learners attending classes with fewer than 40 learners achieved significantly higher scores than learners in classes with more than 40 learners.

21. Mathematics and science resource availability in the classroom was significantly and positively associated with academic achievement. Eighty-three percent of mathematics learners and 58 percent of science learners had their own workbooks. Learners with their own workbooks achieved significantly higher scores than learners sharing a workbook or those without one.

22. 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. About half of the Grade 5 learners reported having a computer at home, while one-third of learners had access to a computer at school. The lack of computers and connectivity in both homes and schools will further disadvantage South African learners, especially the poor.

B. IMPLICATIONS AND RECOMMENDATIONS FROM THE SOUTH AFRICAN GRADE 5 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. What do the TIMSS 2019 results tell us about the health of the South African Intermediate Phase education system? The Medium-Term Strategic Framework (MTSF) (DPME, 2020) and the Action Plan to 2024 (DBE, 2020a) are useful reference points to monitor and evaluate performance, as well as discuss the recommendations for improving achievement outcomes.

One of the five fundamental goals for the country, stated in the MTSF (2019–2024), is that "our schools will have better educational outcomes and learners [will] be able to read for meaning". We recommend extending this goal to include "and learners acquire basic mathematical skills". *The Action Plan to 2024* (DBE, 2020a) also includes the outcome goal of "improved quality of learning outcomes in the Intermediate and Senior Phases, with inequalities reduced by 2024".

In this section we focus on two aspects:

1. How do the results from Grade 5 TIMSS 2019 assist South Africa to monitor and evaluate mathematics and science achievement and achievement gaps in the Intermediate Phase?

2. Based on the TIMSS 2019 results, what factors have been identified to improve Intermediate Phase mathematics and science achievement?

Monitoring mathematics and science achievement and achievement gaps in the Intermediate Phase

As described in points 1 to 5 above, the Grade 5 mathematics achievement scores were low, unequal, and socially graded and there was no improvement in achievement scores between the TIMSS 2015 and 2019 cycles.

1. From the TIMSS data we were unable to explain why the Grade 5 achievement scores did not increase between the two cycles. This is perplexing as the TIMSS mathematics scores increased at Grade 9. To understand why there was no improvement in the Intermediate Phase, we recommend a review into the primary school sector, including a focus on issues such as support provided to primary schools in comparison to secondary schools, the effectiveness of interventions in Foundation Phase teaching and learning, and the nature of teaching, learning and assessments in primary schools.

2. The MTSF (2019–2024) set a target score of 426 points for Grade 5 mathematics in the TIMSS 2023 cycle. Based on the rate of mathematics achievement improvement of 4.6 points per year for TIMSS Grade 9 (Reddy et al., 2022) we predict that the Grade 5 TIMSS 2023 mathematics score will not improve by 52 points from the TIMSS 2019 score to reach the MTSF target of 426 points in TIMSS 2023.

   Further, we anticipate that the effects of the Covid-19 pandemic on the loss of teaching and learning time will negatively affect learning outcomes with decreases in achievement scores. Covid-19 amplified all inequalities and learners in no-fee schools will experience higher learning losses than learners in fee-paying schools. Soudien, Reddy and Harvey (2021) speculated a learning loss of 4.1 percent for the 2020 year.

   To have a true measure of the effects of the pandemic on learning outcomes, especially as it applies to learners in fee-paying and no-fee schools, South Africa needs to continue to participate in achievement studies that measure trends over time.

3. South African achievement continued to be *unequal and socially graded*. Achievement gaps continued to be linked to socioeconomic backgrounds, gender, spatial location, attending fee-paying versus no-fee schools, and the province within which the school was located. This confirms the well-known narrative that, in general, advantage begets advantage, and home disadvantages continue to school. Subsequent trend measures will allow us to measure decreases in achievement gaps and how schools contribute to equalising learner achievement.

4. TIMSS 2019 introduced the first science assessment at the Intermediate Phase for South Africa. The baseline measure of science knowledge and skills in the Intermediate Phase were: the average science achievement scale score was 324 (4.9), only 28 percent of learners had acquired basic scientific knowledge and the achievement distribution inequality was 434 points.

Lower science scores were much more apparent in the more disadvantaged schools and provinces, suggesting that additional barriers (e.g. language of instruction, access to general and specific science resources, ability to write sentences and paragraphs, and educator specialist knowledge) have an impact on the teaching and learning of science.

While national and provincial authorities have focused on mathematical improvement programmes there has been less attention, support, and resources for the science subjects. We recommend that the teaching and learning of the science subjects, especially in primary schools, be given more attention.

What factors can improve mathematics and science achievement?

In Chapter 9 Figure 55, we showed the amount of achievement variance accounted for by the different co-variates in our multivariate model. The quintile rank of the school was strongly and significantly associated with mathematics achievement and accounted for 30 percent of the variation. The quintile rank of the school, in a way, encompasses the school's resources and environment. The features of the home environment (both SES and home learning activities) accounted for 21 percent of the variation, while individual-level characteristics (gender, age, language proficiency) explained 16 percent of the variation. Learners' educational attitudes, and educator and classroom characteristics, each accounted for 20 percent of the variance. The principal and school-level characteristics explained 32 percent of the variance.

We have shown that conditions in the home explain much of the achievement variance. There are many barriers for learners entering schools – home socioeconomic conditions and the location of the school – which are strongly correlated with each other and lead to multiple deprivations for most learners.

Education is a societal matter with many stakeholders. There are many 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.

However, within the present context we have shown, there are still a set of factors within schools and classrooms, as well as individual characteristics, that can be affected by policy.

5. Our major recommendation is that solid foundational knowledge in mathematics and science is critical for future schooling and educational success.

   5.1. We recommend prioritising the **first 1 000 days of formal learning**, i.e. Grade RR, R and 1, to establish strong educational roots and build solid foundations. The Basic Education Laws Amendment Bill, 2021, among other amendments, seeks to make learners' attendance of Grade R classes compulsory (92% of learners already attend Grade R). The Curriculum and Assessment Policy for the Foundation Phase of schooling includes the curriculum for Grade R classes.

   5.2. The National Development Plan (2012) proposed two years of pre-school attendance to improve learning outcomes. Our earlier analysis and the literature confirm that learners with two years of pre-school attendance achieve significantly higher achievement scores than those attending for one year or less, supporting the recommendation that Grade RR also be made compulsory.

   5.3. Early learning must go beyond access to include the provision of high-quality learning experiences in Grade R and RR. Thus, we recommend that Grade R and RR classes be linked to primary schools, especially for children who will attend no-fee schools. In these two years children must be in cognitively rich and stimulating environments that focus on first-language development and reading with meaning, basic computational skills, and writing simple sentences.

   5.4. Children start Grade 1 at different levels of school readiness which impacts on their early learning experiences and predicts their later achievement. The School Readiness programme promised in the National Development Plan and the MTSF (2019–2024) must be developed and implemented. Grade 1 classes should spend the first two weeks of school implementing the School Readiness Baseline Assessment to identify how learners perform and subsequently design activities to provide additional support (using teaching assistants) to learners who may otherwise be left behind.

5.5. For those parents that may be unable to participate in educational play with their children, an alternative could be in the form of high quality, engaging and interactive educational programmes broadcast through the public radio and television network. This could be achieved through a collaboration with the Department of Science and Innovation and the South African Agency for Science and Technology Advancement.

We now discuss other school factors that could contribute to improving educational achievement.

6. Learners who were at the correct age for Grade 5 achieved significantly higher scores 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 be supported to acquire the essential foundational knowledge and skills and meet the minimum learning requirements before progressing to the next grade.

7. While mathematics and science achievement scores were significantly higher for girls than for boys in the bivariate analysis, this advantage decreased in the multivariate model, suggesting there are interaction effects with other factors (especially age). Schools (and policy) must pay additional attention to the learning patterns of boys and the support that must be provided to keep them in school and improve their learning outcomes.

8. While proficiency in the language of learning and teaching matters, it is not the only language factor affecting achievement. We also recommend the importance of good language development for all languages from the early learning experiences. Enhanced first language development will facilitate better access to the second language.

9. There were significant achievement differences between schools located in urban areas and those in remote rural areas. With half the learners in no-fee schools located in rural areas there is a need to prioritise additional support and investment for learners in these settings to help decrease gaps in attainment and provide fair and equal access to educational opportunities.

10. School climate matters. As we noted in Section A point 18 earlier, compared to other TIMSS participating countries, South Africa reported the highest percentage of unsafe conditions and levels of ill-discipline, as well as disruptive behaviour and incidences of bullying in schools. While the Department of Basic Education has published the National School Safety Framework (2016) to support schools on school climate matters, schools may need further support with the implementation of strategies to improve their school climate. The disruptive school climate reflects what happens in the communities surrounding the schools, and schools would need to work with the surrounding community to improve safety.

11. School resources matter. Most classes (especially in no-fee schools) had more learners than the policy stipulation of 40 learners. If learners are in classes of fewer than 40 learners, this would assist educators in terms of better classroom management and would decrease the level of ill-discipline and classroom disruptions, thus promoting better teaching and learning, and leading to improved achievement. To reduce class sizes, the first step would be an audit of how educators are used in schools and how timetables and lessons are scheduled.

12. Educational resources matter in classrooms. A quick and easy win is for all learners to have their own copy of a mathematics and science workbook.

13. Educator qualifications and knowledge are key factors (under the right conditions) that are associated with enhancing mathematics and science learning. About 60 percent of learners were taught by educators with, at least, a degree qualification and reported specialist knowledge. South African educators reported one of the highest levels of attendance at professional development courses.

    However, the achievement results of learners are not associated with reported educator qualifications or their attendance of professional development programmes. We do not have 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.

14. As instructional clarity is a significant factor influencing achievement, educators must be supported to design their mathematics and science lessons to promote high instructional clarity and emphasise academic success. Examples of strategies that promote instructional clarity include giving learners an opportunity to explain their answers, relate their lessons to daily life, and bring interesting materials to class and complete challenging exercises; and educators linking content to learners' prior knowledge and encouraging discussion among learners.

15. Two-thirds of the TIMSS assessment items demanded higher level cognitive reasoning. The South African Curriculum and Assessment Policy Statement (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. The CAPS cognitive levels should set a path to incrementally decrease the proportion of items at the knowing level, and to increase the proportion of items at the applying and reasoning levels. Further, national assessment studies must also include items that require learners to write an explanation, rather than only respond to multiple choice items.

16. Another strategic classroom intervention is to improve learners 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.

17. The observed influence of non-cognitive factors, such as self-reflection of ability, on achievement (which we recognise is mutually reinforcing), provides an opportunity to encourage learners to honestly evaluate their abilities and recognise the role of personal responsibility and effort to improve achievement.

In conclusion

The South African education system is fragile, and the coronavirus pandemic has dealt it a major blow, especially for the poor and most vulnerable. Building back better, within the context of limited financial and other resources, to improve education levels requires the state to make prudent and timely decisions about those programmes and interventions that would provide the best chances for most children in the future.

From the evidence, prioritising the first 1 000 days of a child's formal schooling by building strong educational foundations is an important leverage point to improve educational performance. This is especially so for learners in no-fee schools whose learning losses have been exacerbated because of the coronavirus pandemic. Within the context of school closures and disruptions, and reduced and streamlined curricula over the last two years, our recommendation is to focus on building the reading, writing and computational skills in the earlier years. This would provide a strong foundation on which all other learning will depend.

As is the case with nearly all research investigating the influences on learner achievement, there is no single 'silver bullet' that will fix low performance and remediate years of unequal and socially graded performance throughout the system, but these results 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.

The main stages in the design and planning for TIMSS are discussed as follows:

- Translating and preparing assessment instruments and contacting schools;
- Field testing of instruments;
- Main administration of the Grade 5 TIMSS 2019 assessments;
- Scoring of constructed responses; and
- Creating the Grade 5 TIMSS 2019 data files.

Translating and preparing assessment instruments

The HSRC adapted the assessment instruments for South Africa and translated them from English to Afrikaans in preparation for the 2019 assessment administration. The adaptations included changing some names to those that South African learners would be more familiar with and changing terminology such as 'gas' to 'petrol', and 'meters' to 'metres'. These adaptations and translations were documented using the National Adaptations Forms which were verified by the International Association for the Evaluation of Educational Achievement (IEA) to assess if the national adaptations were 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.

In each TIMSS cycle, countries are able to add items to the contextual questionnaires that are nationally relevant. The HSRC added several items (e.g. province and school quintile) into the questionnaires to provide more contextually relevant information.

Field testing of instruments

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:

- Trial various strategies in administering the home questionnaire;
- 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 during the administration of the main survey.

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 in each school.

Main administration of TIMSS 2019

Consistency across countries is key and the international TIMSS team thus developed a set of procedures and documents to guide countries through the data collection phase, including a test administrator manual and two basic procedures.

Test Administrator Manual

The Test Administrator Manual detailed the procedures that had to be followed when administering the achievement booklets and Learner Background Questionnaire. This was a comprehensive document which provided details about preparing for each assessment, completion of the Learner Tracking Form and the Test Administration Form, the timing of the testing sessions, correct procedure to follow, and how to administer the assessment. The manual included the instructions to learners as a script which was to be read-out by the test administrator.

The Test Administrator Manual was used for training sessions conducted by the HSRC with all fieldworkers prior to the administration of the main study. The training covered procedures to be followed in administering the tests, procedures for administering the questionnaires, processes to follow should any problems arise (trouble shooting) and how to fill in the required administration forms.

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. South Africa administered the main study in the last two weeks of October into the first week of November 2018. The HSRC worked closely with the Department of Basic Education and provincial coordinators to ensure that the study was successfully administered. Specifically, the provincial coordinators assisted with school contact information while playing the role of the mediator between HSRC and the schools.

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 IEA selected and trained an International Quality Control Monitor who monitored the administration process in 15 South African schools. This process was independent of the HSRC.

Scoring the constructed response items

TIMSS assessment items comprised both multiple-choice and constructed-response (open-ended) items. The constructed-response (open-ended) items represent approximately 50% of the TIMSS assessments, hence the reliability and validity of scoring is 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 teachers and university students to conduct the scoring. The constructed-response items were scored by hand, and learners' responses were scored consistently, regardless of who was assigning the scores. As a quality control measure, five 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 in the Cross-country Scoring Reliability Study (CCSRS). The purpose of the CCSRS was to measure the consistency of scoring the constructed-response items across countries, while the TSRS measured whether constructed-response items were consistently scored in the same manner by scorers in 2015 and 2019. 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 national 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 complete, 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 by 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 the Intermediate Phase (Grade 4-6) 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 combined subject of Natural Sciences and Technology subject in Grade 4. It is a compulsory subject for all learners in the Intermediate Phase (Grade 4-6). South Africa follows an integrated science curriculum and the CAPS document (DBE, 2011b) sets outs the aims and the content areas covered in the subject.

Learners should:

- Be able to complete investigations, analyse problems and use practical processes and skills in designing and evaluating solutions;
- Have a grasp of scientific, technological and environmental knowledge and be able to apply it in new contexts; and
- Understand the practical uses of Natural Sciences and Technology in society and the environment and have values that make them caring and creative citizens.

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)

NOTES

NOTES

The South African TIMSS 2019 Grade 5 Results: Building Achievement and Bridging Achievement Gaps

The TIMSS 2019 Grade 5 study was administered in October/November 2018 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. For Grade 5, TIMSS 2019 was the second cycle in which learners wrote the mathematics assessment and the first time they participated in the science assessment. TIMSS 2019 collected learner achievement data in the core subjects of mathematics and science, as well as contextual information from learners, parents or guardians, educators and school principals which enabled the exploration of factors that are associated with Grade 5 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, inferential and multivariate analyses 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 the key results and its implications for the Intermediate Phase of the South African education system.

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