THE Gauteng Province TIMSS 2019

Grade 9 Results

Building Achievement and Bridging Achievement Gaps

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Dr Vijay Reddy
TIMSS National Research Coordinator
Human Sciences Research Council

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LIST OF ACRONYMS

4IR	Fourth Industrial Revolution
CAPS	Curriculum and Assessment Policy Statements
CI	Confidence Interval
CR	Constructed response
DBE	Department of Basic Education
EMIS	Educational Management Information System
FET	Further Education and Training
GDE	Gauteng Department of Education
GDP	Gross Domestic Product
GDPR	Gross Domestic Product of Region
GER	Gross Enrolment Rate
GHS	General Household Survey
HDI	Human Development Index
HER	Home Educational Resources
HSRC	Human Sciences Research Council
IEA	International Association for the Evaluation of Educational Achievement
IRT	Item Response Theory
LoLT	Language of Learning and Teaching
MCQ	Multiple Choice Question
NCS	National Curriculum Statement
NDP	National Development Plan Vision 2030
NEIMS	National Education Infrastructure Management System
OECD	Organisation for Economic Co-operation and Development
PIRLS	Progress in International Reading Literacy Study
RSA	Republic of South Africa
SA-SAMS	The South African School Administration and Management System
SE	Standard Error
SES	Socioeconomic Status
StatsSA	Statistics South Africa
TIMSS	Trends in International Mathematics and Science Study
UAE	United Arab Emirates
WinW3S	Within-school Sampling Software

READER'S GUIDE

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

TIMSS ACHIEVEMENT

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

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

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

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

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

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

HOW LEARNERS WERE ASSESSED

TIMSS cognitive domains: The three hierarchically organised cognitive domains are knowing, applying and reasoning. Knowing covers the facts, concepts and procedures learners need to know, and 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 yellow 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 yellow 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 inequality** within countries is defined as the score difference between the 5th and 95th percentile.

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

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

IMPORTANT STATISTICAL TERMS

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

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

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 CI 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.

An important value in multivariate analysis is the **R-squared value**. This is a statistical calculation that tells us the proportion of the variation in the dependent variable (achievement in the case of the TIMSS report) that is explained from the independent variable(s).

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 (based on the income levels of the community surrounding the school, the unemployment rate and the level of education of the community) was calculated for each public school by the Department of Basic Education. These schools are categorised into five 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 these schools 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: GAUTENG TIMSS 2019 GRADE 9 RESULTS

In the 2019 cycle of the Trends in International Mathematics and Science Study (TIMSS), the Gauteng Department of Education (GDE) sought more precise provincial achievement estimates and therefore increased the provincial sample size from 30 to 150 schools at the Senior Phase (Grade 9). The data from the Gauteng province sample form part of the overall South African results and are also reported separately as a self-standing entity called a 'benchmarking participant' in the international TIMSS report.

Participation in TIMSS allows countries and benchmarking participants to evaluate their learners' achievement and monitor the health of their education systems over time. TIMSS also allows participants to compare their achievement against other participants. In addition, the study allows the exploration of how contextual factors are associated with learners' mathematics and science achievement.

In August 2019, the Human Sciences Research Council (HSRC) collected achievement and contextual data in 150 secondary schools from 150 principals, 150 mathematics educators, 150 science educators, and 5 633 Grade 9 learners in the Gauteng province. The analysis of data was informed by a framework focused on how to build achievement and bridge achievement gaps.

MATHEMATICS AND SCIENCE ACHIEVEMENT, ACHIEVEMENT TRENDS AND ACHIEVEMENT GAPS

The Gauteng Grade 9 learners achieved an average scale score of 421 (SE 3.0) on the mathematics assessment and 422 (SE 3.9)[1] on the science assessment. The results showed that 58 percent of mathematics learners and 57 percent of science learners had acquired the basic content knowledge and skills in each subject. Furthermore, six percent of mathematics learners and 11 percent of science learners achieved at the higher levels (scores higher than 550 points) meaning that they were able to solve complex problems.

From 2011 to 2019, Gauteng's achievement improved by a statistically significant 24 points in mathematics and 26 points in science. The annual average achievement improvement rate from 2011 to 2019 was 3 points for mathematics and 3.3 points for science, both lower than the improvement rates for South Africa over the same period.

While the Gauteng province achieved the second highest score of the South African provinces, there was high achievement inequality within the province. The achievement difference, between the 5th and 95th percentiles, was 253 points for mathematics and a higher 324 points for science.

Figure 1 reports the achievement inequality when the scores were disaggregated by the quintile rank of the school. The average mathematics and science achievement scores of learners in Quintile 1 to 3 schools were not statistically different from each other, while learners in Quintile 4 schools achieved significantly different scores from all other quintiles. Learners in Quintile 5 and independent schools had similar achievement.

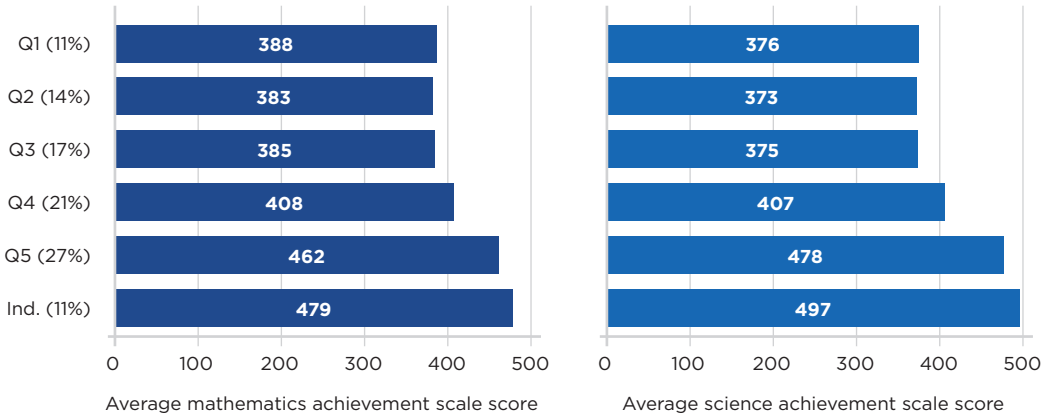
The GDE is made up of two unequal systems of education. The achievement gap (average difference between no-fee and fee-paying schools) was 61 points for mathematics and 81 points for science.

On average, close to 40 percent of learners in Quintile 1, 2 and 3 schools; 55 percent in Quintile 4 schools and 80 percent in Quintile 5 and independent schools demonstrated that they had acquired basic mathematical and scientific knowledge and skills.

Gauteng learners in no-fee schools achieve similar scores to the average national mathematics and science scores. As in previous TIMSS cycles, achievement scores were unequal and socially graded. Achievement gaps in the Senior Phase continued to be linked to where learners lived and learned: their socioeconomic background, gender and age, school fee-paying status and their proficiency in the language of the test.

1 The standard error (SE) indicates how accurate the mean of any given sample is likely to be compared to the true population mean.

Figure 1: Gauteng mathematics and science achievement scale scores by quintile rank of the school (% learners)



INDIVIDUAL CHARACTERISTICS AND ACHIEVEMENT

The learner characteristics of gender, age and proficiency in the language of the test explained 21 percent of the achievement variance.

The average age of girls was 0.5 years younger than boys, with 70 percent of boys at the correct age for the grade compared to 86 percent of girls. Although boys scored significantly higher achievement than girls, these results must be interpreted in line with the selection effects of staying in school.

One in five learners were overage for Grade 9 (26% in no-fee schools and 17% in fee-paying schools). Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage.

The Gauteng province is linguistically diverse with representation of all 11 official languages in schools. In TIMSS 2019, isiZulu was the most common language spoken at home (22%) followed by Setswana (16%) and Sesotho (15%).

Four in ten Grade 9 Gauteng learners (22% in no-fee schools and 51% in fee-paying schools) reported that they frequently spoke the language of the test at home, which is used as a proxy for proficiency in the language of the assessments. Learners who were more proficient in the language of the test achieved significantly higher mathematics and science scores than those who were less proficient.

THE HOME ENVIRONMENT AND ACHIEVEMENT

The Gauteng households where learners lived were categorised as 37 percent high socioeconomic status (SES), 34 percent as medium SES and 29 percent as low SES. Close to half the learners (46%) in no-fee schools, compared with 17 percent of learners in fee-paying schools, came from homes characterised as low SES.

The socioeconomic conditions (assets and parental education) in which learners live and learn explained 23 percent of the achievement variance. There was a significant, positive association between the SES of the household and learners' mathematics and science achievement, thus confirming the enduring finding in the literature that the circumstance of one's birth continues to be a predictor of a learner's educational and life trajectory.

THE SCHOOL AND ACHIEVEMENT

The profile of learners by population group[2] in Grade 9 was: 83 percent Black African, eight percent White, seven percent Coloured, and two percent Indian/Asian. Learners attending Quintile 1, 2, 3 schools were, on average, 96 percent Black African; and Quintile 4 and independent schools were 80 percent Black African. Black African learners made up 64 percent of the Quintile 5 cohort. Almost all White and Indian/Asian learners attended Quintile 5 and independent schools.

The school climate matters for higher achievement. Most learners attended schools that were characterised by unsafe conditions, discipline problems in the school and classroom, learner bullying and low emphasis on academic success. Learners who were in safer schools, with hardly any discipline problems in the school and classroom, and who hardly experienced any form of bullying, achieved significantly higher mathematics and science scores.

There were significantly higher levels of ill-discipline, unsafe conditions and incidences of bullying behaviours in no-fee schools than in fee-paying schools. Parental expectations and support for learner achievement were significantly higher in fee-paying schools than in no-fee schools.

CLASSROOMS AND ACHIEVEMENT

The average class size of the Grade 9 TIMSS sample was 41 learners. In Quintile 1 to 4 schools, the average class sizes clustered around 45 learners, and in Quintile 5 schools the average was 36 learners. Learners in classes with fewer than 37 learners achieved significantly higher average mathematics and science scores than those in classes with more than 37 learners.

Over 80 percent of Gauteng learners had access to their own mathematics and science workbooks, while three-quarters of learners had access to their own textbooks. Access to one's own workbook or textbook influenced learners' achievement score.

While the Gauteng province has implemented plans to improve access to digital devices and introduce digital platforms for learning and instruction, the access and usage of computers in Grade 9 classrooms was very low. Two-thirds of Grade 9 learners had no access to a computer in their classes.

The educator and classroom characteristics explained 24 percent of the achievement variation.

LEARNER ATTITUDES TO MATHEMATICS AND SCIENCE

Positive attitudes and higher achievement go hand in hand, with each mutually reinforcing the other. Learner attitudes explained 13 percent of the achievement variation. Learners who liked learning mathematics and science and had a realistic self-reflection of their mathematical and scientific abilities (i.e. confidence in learning) achieved higher scores.

THE MATHEMATICS AND SCIENCE CURRICULUM AND ACHIEVEMENT

The TIMSS assessment had two-thirds of the items requiring learners to use the higher cognitive skills of application and reasoning. Comparatively, the South African Curriculum and Assessment Policy Statements (CAPS) has a higher focus on the skills of knowing and solving routine problems, and a limited emphasis on the skills of applying and reasoning.

Three-quarters of the TIMSS mathematics and science content was reported to have been taught in the CAPS before learners took the assessment. When compared to the Gauteng average mathematics scores, learners performed significantly better in algebra and experienced more difficulty in the data and probability as well as geometry content domains. When compared with the average provincial science score, learners scored significantly lower in the biology domain and significantly higher for the physics domain.

2 This is based on self-identification from learners reports. We use the term population group only to trace changes historically.

IMPLICATIONS AND RECOMMENDATIONS FROM THE TIMSS GAUTENG RESULTS

From the Gauteng TIMSS 2019 results we highlight four high-level recommendations to improve educational outcomes at the Senior Phase in Gauteng province.

1. **Continue monitoring achievement:** As a higher performing South African province, but lower in international comparisons, the Gauteng province must continue participation in the periodic international trend assessment to monitor its achievement standing in relation to other countries and to monitor the achievement changes over time.
2. **Improve school functionality and promote whole school development:** There is large achievement variation between no-fee and fee-paying schools, as well as within fee-paying schools. Our findings support the GDE strategic priority for whole school development and improving functionality. Schools and classrooms do have the capacity to positively improve educational outcomes. In Gauteng, the educator and classroom factors explained 24 percent of the achievement variance, while the principal and school factors explained 28 percent of the variance.
3. **Focus on school safety and academic climate:** Compared to most TIMSS countries, Gauteng schools experienced higher levels of safety problems, ill-discipline in schools, disruptive behaviour in classrooms and incidences of bullying. Similarly, there was a lower reported emphasis on academic success compared to most TIMSS countries. These school climate factors are positively associated with achievement. Improving on these characteristics and indicators includes examining what the school does to improve the school climate, as well as how it involves the learners, parents and the community in school matters. In implementing measures for safer schools, we recommend an additional performance indicator for school safety be included, namely 'the number of schools that have regular community fora and parent engagements related to school safety and learning'.
4. **Pay greater attention to the non-cognitive and attitudinal dimensions related to learning as a lever to improve learning:** Learner confidence is part of a virtuous cycle that should be fostered and developed: doing well in mathematics and science improves feelings about, and one's capability in, these subjects. The honest reflection of one's capability is a recognition of what needs to be done to improve achievements. We recommend that the GDE periodically administers short, validated instruments to obtain a profile of learners' attitudes and motivation. The results from this tool could be the basis of the conversation between the school and learners to improve their attitudes and behaviours towards learning.

CONCLUSION

The Gauteng education system, while one of the better performing South African provinces, is highly unequal with wide achievement gaps. The achievement patterns are reflective of both the lingering apartheid legacy as well as the present socioeconomic and sociocultural conditions. While many factors that influence learning outcomes may be outside of the control of schools (e.g. home SES or violence in the community), there are practices within the school that can be changed to improve achievement.

To improve the education level of Gauteng, there must be intentional and carefully targeted programmes for Quintile 1, 2 and 3 schools, as well as programmes to improve achievements in the better resourced schools. Raising the educational outcomes of these two groups of learners will contribute to raising the overall provincial achievement levels. These interventions are even more important in the wake of the coronavirus pandemic that has dealt the system a major blow – especially for the most vulnerable learners.

In 2019 only 37 percent of Gauteng learners sat for the mathematics matriculation (Grade 12) examination compared with 63 percent for the mathematical literacy subject. However, close to 60 percent of the Grade 9 learners achieved scores above 400 points in TIMSS, signalling that they had acquired the basic skills and competences in mathematics and science. These learners would more than likely succeed if they chose mathematics in the Further Education and Training phase, and it is therefore important to investigate why learners are not choosing to continue with mathematics after Grade 9.

TIMSS 2019 has provided an evaluation of the 2019 Gauteng education system, confirming that learners experienced multiple barriers to achievement. While there is no one 'silver bullet' that will fix low performance and remediate years of social imbalance throughout the education system, these provincial results highlight that there are many areas that can and must be improved.

SECTION A

FRAMING THE TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY FOR THE GAUTENG PROVINCE AS A BENCHMARKING PARTICIPANT

The Trends in International Mathematics and Science Study (TIMSS) is an assessment of the mathematics and science knowledge of fourth or fifth and eighth or ninth grade learners around the world. TIMSS allows participating countries and regions 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. Thirty-nine countries and seven 'benchmarking participants' (i.e. states, counties, provinces or cities) participated in the TIMSS 2019 cycle at Grade 8 or 9.

TIMSS was first administered in South Africa in 1995, and subsequently every four years, except the 2007 cycle. In previous cycles of TIMSS, the Gauteng province participated as part of the national study, with a sample size of approximately 30 schools. For the TIMSS 2019 cycle, the Gauteng Department of Education (GDE) sought more precise provincial achievement estimates. The sample size for Gauteng in TIMSS 2019 was thus increased to 150 schools. The data from this sample form part of the overall South African results but, with the increased sample size, Gauteng results are also reported separately as a self-standing entity called a benchmarking entity in the international TIMSS 2019 results.

To frame the reading of the TIMSS 2019 Gauteng results in this report, this chapter will focus on two main aspects: (i) the Gauteng educational landscape and (ii) the design and methodology of TIMSS 2019 with reference to the Gauteng province as a benchmarking participant.

CHAPTER ONE

FRAMING THE TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY IN THE GAUTENG PROVINCE

The Gauteng province participated as an independent 'benchmarking entity' in TIMSS 2019. Benchmarking participants are regional entities such as provinces or states or city regions that requested more precise achievement measures and identification of the factors that are associated with achievement. The benchmarking participants were Moscow City (Russian Federation), Quebec and Ontario provinces (Canada), Dubai and Abu Dhabi (United Arab Emirates (UAE)) and the Western Cape and Gauteng provinces (Republic of South Africa (RSA)).

South African Grade 8 or 9 learners have participated in TIMSS since 1995, except for 2007, creating a 24-year achievement dataset which is valuable for monitoring changes in educational outcomes. The most recent cycle was conducted in 2019 and Reddy et al. (2022) report the South African TIMSS 2019 Grade 9 results. Since TIMSS 1999, the South African sample has been stratified by province with the provincial sample sizes being between 25 and 35 schools. In these assessments, the average Gauteng mathematics and science scale scores were significantly higher than the national average score.

To further explore this finding, in TIMSS 2019, the sample size for Gauteng was increased from 30 to 150 schools. This province thus participated in TIMSS 2019 as part of the national sample but also as an independent 'benchmarking entity'. This larger sample size allows a more precise (with lower standard errors (SE – refer to Reader's Guide)) measure and identification of the factors that are associated with achievement. Participation as a benchmarking participant thus provided the opportunity to understand the texture and dynamics of Gauteng achievement in mathematics and science. This larger sample also allowed for analysis to identify factors that can predict Gauteng learners' Grade 9 achievement.

This Gauteng TIMSS 2019 Grade 9 Results report describes achievement in mathematics and science for the province. While Gauteng may show similar educational characteristics and factors linked to achievement as the overall South African patterns, this provincial dataset will allow us to further explore the unique achievement patterns and factors influencing achievement in the province.

To frame and guide this analysis, we must understand the demographic, socioeconomic and educational context of the province as well as how these influence achievement patterns. In the discussion that follows, we summarise the Gauteng demographic and socioeconomic context followed by a description of the size and shape of the Gauteng educational system and its key challenges. We conclude the section by outlining the debates relating to achievement gaps.

1.1. GAUTENG DEMOGRAPHIC, SOCIAL AND ECONOMIC CONTEXT

Gauteng is the smallest province in South Africa but comprises the largest share of the population (Statistics South Africa (StatsSA), 2016). It has an area of 18 182 km^2 (1.5% of South Africa) and, in 2019, was home to 15.2 million people. This equates to a quarter of the South African population (26%) (StatsSA, 2019a). Gauteng thus has a higher population density than the national average (675 people/km^2 compared to a national average density of 42 people/km^2) (Gauteng Provincial Department, RSA, 2020).

Established in relation to the discovery of gold in the 19th century and subsequent mining activities and investments, Gauteng is classified as largely an urban province. Over 85 percent of Gauteng's population resides in its three metropolitan municipalities: the City of Johannesburg, which is the financial capital; the City of Tshwane, which serves as the administrative capital; and the City of Ekurhuleni, which is a major industrial hub (Mushongera et al., 2018; StatsSA, 2016). Gauteng also has two other administrative district municipalities: West Rand and Sedibeng (StatsSA, 2016).

Gauteng has a very diverse linguistic profile that reflects all eleven official languages. The main first languages spoken by the Gauteng population are: 23 percent isiZulu, 13 percent Sesotho, and 11 percent English (StatsSA, 2016). All municipalities are predominantly Black African, with the population groups within Gauteng being

as follows: 82 percent Black African, 12 percent White, three percent Coloured, and three percent Indian/Asian (StatsSA, 2020b)[3]. Mushongera et al. (2018) note that there is a higher concentration of Black Africans in areas with lower economic activity. These areas are associated with fewer employment opportunities, and this is a visible legacy of apartheid segregation policies. Socioeconomic and other forms of inequality are a concern for Gauteng.

Gauteng, as noted in its plan *Growing Gauteng Together 2030*, is the "economic hub of South Africa" (Gauteng Provincial Government, RSA, 2020). As it is viewed as a place of opportunities, it attracts many people from other South African provinces, as well as other countries (ibid, 2020). The high rate of in-migration, primarily of young people seeking economic opportunities, explains the youthful population of Gauteng. Fifty-nine percent of the population is below the age of 35 years and 22 percent is aged 5-19 years (GDE, 2020; Gauteng Provincial Government, RSA, 2020; StatsSA, 2016). As a result of high in-migration with 1 643 590 migrants between 2016 and 2021 (an annual average of 328 718) of which 106 656 were learners in 2019, some public-school classrooms experience strained teaching resources, overcrowding, and reduced contact time in schooling (GDE, 2020). The high-density population also causes challenges related to unemployment, pressure on infrastructure and service delivery, urbanisation and crime (GDE, 2020; Gauteng Provincial Government, RSA, 2020; Mushongera et al., 2018).

Gauteng has an unemployment rate of 37 percent (StatsSA, 2022b). Youth unemployment continues to be one of Gauteng's most pressing economic and social problems with an unemployment rate of 49 percent in this group (GDE, 2020; Gauteng Provincial Government, RSA, 2020). Gauteng furthermore has a provincial poverty rate of 33 percent (StatsSA, 2015). In 2018, Gauteng was home to a substantial percentage of multi-dimensionally deprived children (64% compared to the national average of 62%) (StatsSA, 2020a). Children are considered multi-dimensionally poor if they are deprived of three or more of the seven dimensions of well-being (water, sanitation and waste disposal; housing; nutrition; protection; health; information; and education related to school attendance, delays in attendance and school facilities) (StatsSA, 2020a).

The high level of crime in Gauteng is the primary threat to personal safety. There is furthermore a spill-over effect of societal problems from the communities to the schools located within them, with concerns around the safety of learners caused by violence due to gangsterism, substance abuse, and learners themselves taking weapons to school (Gauteng Provincial Government, RSA, 2020). These problems are exacerbated by overcrowding in schools which is related to the high rates of learner in-migration (GDE, 2020).

Turning to the overarching economy, Gauteng and the Western Cape are the two most economically affluent South African provinces. The size of the Gauteng economy is expected to double over the next 11 years, from a current size of R1 trillion to slightly above R2 trillion (Gauteng Provincial Government, RSA, 2020). In 2017, Gauteng had a Gross Domestic Product of Region (GDPR) per capita of R111 171 in comparison to the South African GDP of R81 875 (StatsSA, 2017). The Human Development Index (HDI)[4] for Gauteng is the second highest of all provinces at 0.73[5], but this is undermined by the high levels of social inequality (Gumede, 2021).

The dominance of the Gauteng economy is unsurprising given the number of industries that are represented in the province: construction, electricity, finance, government, manufacturing, personal, trade and transport (StatsSA, 2017). The economy is dominated by the tertiary sector (finance, government, personal, trade and transport) which employs 81 percent of the Gauteng labour force. The secondary sector (construction, electricity and manufacturing) employs 17 percent, while the primary sector (agriculture and mining) accounts for two percent of the labour force (StatsSA, 2022b).

3 We recognise that terms like racial classifications are problematic social constructs from a particular era. However, they need to, and will continue to, be used to monitor progress since the democratic change since 1994. We use the racial terminology common in South Africa and used by StatsSA to describe population groups: Black African, Coloured, Indian/Asian, and White.

4 The HDI is a summary measure of key dimensions of human development. The health dimension is assessed by life expectancy at birth, the education dimension is measured by mean of years of schooling for adults aged 25 years and older and expected years of schooling for children of school entering age. The standard of living dimension is measured by gross national income per capita.

5 From https://globaldatalab.org/shdi/, retrieved 23 March 2022.

The dominance of the tertiary sector and the Fourth Industrial Revolution (4IR)[6] increases the demand for a medium- to high-skilled workforce, especially with skills related to science, engineering and technology. The Gauteng education system is thus challenged to not only provide quality education to all but also to develop other skills in learners such as communication, problem-solving, critical thinking and teamwork (GDE, 2020).

The size and shape of the Gauteng educational system

The Constitution of the Republic of South Africa (Act 108 of 1996) mandates the GDE to provide compulsory basic education (RSA, 1996a) for all learners. The National Education Policy Act (Act 27 of 1996) outlines the concurrent responsibilities of the National and Provincial Departments of Education for planning, provision, governance, monitoring and evaluation (RSA, 1996b). The nine provincial departments of education are responsible for funding decisions and for implementing education policy and programmes in Grades R to 12. The South African Schools Act (Act 84 of 1996) provides a framework for the provision of basic education (RSA, 1996c).

The provision of quality education is the number one priority for the Gauteng Provincial Government (Gauteng Provincial Government, RSA, 2020). The province strives for a "growing, labour absorbing, inclusive, innovative, sustainable and globally competitive economy" (Ibid, p. 13), where education and skills development are aligned to the needs of the province (Ibid, p. 28). The Gauteng government is furthermore cognisant that educational quality and outcomes are aligned to where learners live and learn (Ibid, p. 31).

The GDE mission is thus to provide "functional and modern schools that enable quality teaching and learning to protect and promote the right of every learner to quality, equitable and relevant education" (GDE, 2020, p. 2). Towards this aim, the GDE has introduced support strategies to improve the quality of teaching and learning across the curriculum in all school phases. Strategies supporting mathematics and science education include the General Education and Training Language and Mathematics Strategy (incorporating the Reading component) and the Maths, Science and Technology Strategy. In addition, the Department's School Safety and Security Policy encompasses all measures to combat threats to learners, teachers and school staff including school property. The province's *Strategic Plan 2020–2025* outlines several outcomes to ensure delivery of quality education and developing skills and capacity (GDE, 2020). This is critical to the eradication of poverty, unemployment, and inequality in the province (GDE, 2020). The results from TIMSS 2019 for Gauteng will add further information and assist in monitoring the progress on a number of indicators.

The GDE is divided into 15 schooling districts. Analysis of the Educational Management Information System (EMIS) data showed that most schools in 13 schooling districts were classified as urban. These districts are Ekurhuleni North, Ekurhuleni South, Gauteng East, Johannesburg Central, Johannesburg East, Johannesburg North, Johannesburg South, Johannesburg West, Sedibeng East, Sedibeng West, Tshwane North, Tshwane South and Tshwane West. The remaining two schooling districts, Gauteng North and Gauteng West, had a mixture of schools classified as urban and some classified as rural.

The GDE is made up of 2 071 (74%) public ordinary schools and 742 (26%) independent schools. In 2019, there were 2.2 million learners educated in public ordinary schools (1.4 million learners in 1 404 no-fee public ordinary schools and 800 000 learners in fee-paying schools) and 296 282 learners in independent schools (12 percent of learners in the province) (DBE, 2020c; GDE, 2020).

The Department of Basic Education (DBE) has calculated a poverty index for each school based on income, literacy and unemployment of the community surrounding the school. Each school is classified as one of five quintiles (refer to Reader's Guide), with Quintiles 1 to 3 being the most under-resourced and called no-fee schools. In 2010, the no-fee policy was extended by the GDE to Quintile 4 and 5 schools who were then able to apply for no-fee status. By 2019, 393 Quintile 4 and 64 Quintile 5 schools had successfully made this application and were provided funding by the provincial government. However, this does not change their quintile categorisation (Chanee, 2020). Fifty-eight percent of Gauteng learners now attended no-fee schools; 30 percent fee-paying schools and 12 percent independent schools (GDE, 2020).

6 Digital revolution that is characterised by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

Key measures of the wellbeing of an educational system are whether learners who start school at Grade 1 proceed through 12 years of schooling to reach Grade 12 (i.e. throughput or retention) and how they perform in key school subjects. Grade repetition and the retention of learners in the schooling system are concerns in the province. For example, van der Berg et al. (2019) undertook a cross-section analysis of SA-SAMS data from Gauteng for the period 2015 to 2018 to show the high rate of repetition and dropout in secondary schools. The authors contrasted a pseudo-cohort of Grade 9 learners in 2015 with the actual cohort of Grade 9 learners. The pseudo cohort shows that in 2015 there were approximately 75 000 learners, and this number dropped to 65 000 in 2018, the year in which learners should have reached Grade 12 if they had not repeated or dropped out. Contrasting with the actual cohort we see that only 19 000 of 75 000 Grade 9 learners reached Grade 12 without repeating a grade or dropping out. The remaining 46 000 learners who reached Grade 12 in 2018 were repeaters from earlier cohorts.

A related concern in the province is learner in-migration and the resulting burden on the education system and its infrastructure, as referred to earlier. There is an increased need for resources as well as new schools and classrooms in some areas. Furthermore, the overcrowding of schools places strain on the security and safety processes within schools and causes educator burn-out and absenteeism. The unplanned influx of learners into Gauteng schools also disrupts the planning process, leaving schools at capacity but with some learners still unplaced at the beginning of each year (GDE, 2020).

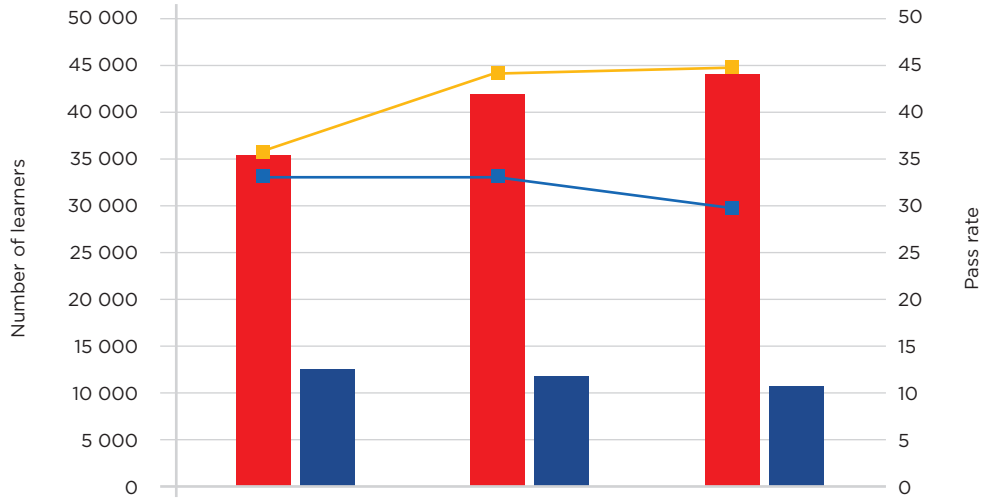
We explored learner outcomes using matriculation results and in particular the number of Bachelor's passes and mathematics passes as an indication of the potential pool of school graduates from Gauteng available to enter post-school education and training institutions, especially in technical areas. Figure 2 shows the trend in learner performance from 2017 to 2019. Over this period, an average of 97 000 Gauteng learners sat for the matriculation (Grade 12) examination each year. The percentage of Gauteng learners obtaining a Bachelor's pass (the minimum qualification to enter university) increased from 36 percent in 2017 to 45 percent in 2019. This is the highest achievement across all provinces (DBE, 2018, 2019c, 2020b).

Learners in the Further Education and Training (FET) phase of schooling (Grades 10 to 12) take either mathematics or mathematical literacy as a school subject. The latter is less difficult and is only accepted as a university admittance subject in some courses. In 2019, across South Africa, 42 percent of learners wrote the mathematics matriculation examination, while 58 percent chose mathematical literacy (DBE, 2020b). For Gauteng, over the same period, 37 percent of learners enrolled for mathematics and 63 percent for mathematical literacy.

We then examined the pool of learners who passed the matriculation examination with a mathematics pass mark higher than 50 percent – this group would be the pool of school leavers who could access the science, technology, engineering, mathematics and health-related tertiary level qualifications. In 2017, 12 325 learners in Gauteng passed mathematics with a score over 50 percent (33 percent of the learners who wrote the mathematics examination and 13 percent of learners who wrote the matriculation examinations). In 2019, this number dropped to 10 542 learners (30 percent of those who wrote mathematics and 11 percent of those who wrote the matriculation examinations).

These numbers are low considering Gauteng's economic and human resource base, its educational infrastructure and the demand for technical qualifications (dependent on school mathematics performance) from the society and the economy. This is also surprising considering the province's past mathematics performance in TIMSS and systemic studies in the earlier grades, and in particular Grade 9.

Figure 2: Number and percentage of learners achieving matriculation with a Bachelor's pass and mathematics pass at higher than 50 percent from 2017 to 2019



	2017	2018	2019
N Bachelor passes	35 012	41 410	43 494
N Math >50%	12 325	11 635	10 542
% Bachelor passes	36	44	45
% Math >50%	33	33	30

Source: DBE (2018, 2019c, 2020b) together with National Senior Certificate data provided by EMIS, DBE.

A focus on achievement and achievement gaps

Ideally, achievement gaps should only reflect differences in ability and effort; however, in most educational systems, the achievement gaps that exist are associated with background factors. There is a rich South African literature documenting the low and unequal educational outcomes (Reddy, 2005; Fleisch, 2008; Reddy, van der Berg, Janse van Rensburg & Taylor, 2012) and uneven labour market outcomes in the country (Bhorat et al., 2017; Case, Marshall & Fongwa, 2018; Rogan & Reynolds, 2016). Research on factors that shape individual educational outcomes has highlighted how race, gender, home background and socioeconomic status (SES), the type of educational institution attended, and geographic location continue to influence the embeddedness of inequality from basic education through to the labour market.

Both scholarly and public debates on the topic of inequality generally distinguish between inequality of outcomes and inequality of opportunities (Ramos & Van der Gaer, 2020; Roemer & Trannoy, 2016). While inequality of outcomes is concerned with disparities in material wealth, income or expenditure; inequality of opportunities attributes differences to circumstances beyond individual control, such as gender, ethnicity, place of birth, or family background (Roemer & Trannoy, 2016). For example, in Gauteng, educational quality remains linked to location, where the poorer performing schools are in townships and inner-city areas (Gauteng Provincial Government, RSA, 2020). The inequality of opportunities framework, in understanding educational inequalities, recognises those parts of inequality caused by circumstances outside individuals' control, which merit compensatory intervention; and parts of inequality that are generated by individual choices, talent and effort which are considered fair and should not necessarily be circumscribed (Roemer & Trannoy, 2016).

In both developed and emerging economies, factors of race and gender, as well as parental wealth and educational attainment, are the main determinants of children's educational success (World Bank Group, 2018). In low-income countries and households, the relationship is more complex, with achievement outcomes being both a determinant and consequence of the stage of development, thus making the journey to improved educational outcomes more complicated. Observations show that children from poor families are less likely to start, progress or complete schooling successfully, and consequently have lower employment outcomes (Duncan et al., 2007).

The framework informing the Gauteng TIMSS 2019 analysis is thus educational inequalities, and in particular achievement and achievement gaps. We acknowledge the significant role of home SES in influencing achievement but interrogate the data to identify ways that schools and classrooms can contribute to equalising achievement. With a focus on **Building Achievement and Bridging Achievement Gaps**, the TIMSS 2019 Gauteng results contribute to monitoring educational achievement outcomes and identifying factors that could contribute to improved achievement scores in the province.

It is in this context and with these policy questions in mind that Gauteng participated in TIMSS 2019. In the next section we discuss the TIMSS 2019 design and methodology and how we implemented the study in the province.

1.2. TIMSS DESIGN AND METHODOLOGY

What is TIMSS?

TIMSS was developed by the International Association for the Evaluation of Educational Achievement (IEA) and is managed by the TIMSS and PIRLS International Study Center at Boston College in the United States. The main goal of TIMSS is to assist countries to monitor and evaluate their mathematics and science teaching and learning, as well as their achievement outcomes, over time and across different grades, as well as allowing for comparison across countries. For full details about the history of IEA and the studies conducted see the IEA website[7].

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

Thirty-nine countries, including South Africa, participated in the TIMSS 2019 cycle for Senior Phase learners in Grades 8 and 9. In addition to the 39 countries, there were seven benchmarking participants, including the Gauteng and Western Cape provinces from South Africa. Benchmarking participants are regional entities (i.e. a part of a country) such as provinces, states or city regions that requested more precise achievement measures, seeking to explain the achievement within the entity. Benchmarking participants thus boosted the sample size to 150 schools to provide more robust achievement measures, and through appropriate statistical analyses, identify factors that influence achievement in their locality.

In addition to the IEA, and the TIMSS and PIRLS International Study Center, a number of 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 Center, oversaw the instrument translation and verification processes, as well as the quality-assurance programme; and IEA Hamburg was responsible for oversight of the data collection, data processing and data analysis.

This section provides an overview of the TIMSS Study Design and Methodology with regards to Gauteng. Administration of the Gauteng TIMSS data collection formed part of, and was conducted parallel to, the national Grade 9 TIMSS data collection. The design and methodology approach and procedures were thus largely the same across the two studies. We provide the operational details and procedures in Annexure 1.

TIMSS in the Gauteng province

Since 1995, the Human Sciences Research Council (HSRC) has conducted TIMSS in South Africa. The country participated at Grade 8 in the 1995, 1999 and 2003 cycles, and at Grade 9 in the 2003, 2011, 2015 and 2019 cycles. TIMSS 2003 included both Grade 8 and 9 learners, and we therefore have a mathematics and science achievement trend measure from 1995 to 2019 for South Africa. Since TIMSS 1999, we reported provincial achievement scores for the Senior Phase (i.e. Grade 8 or 9). Due to the small provincial sample sizes, the provincial achievement estimates had high standard errors (refer to Reader's Guide).

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

Following the TIMSS 2015 Grade 9 results, the GDE requested more precise provincial achievement estimates. The sample size for TIMSS 2019 for this province was therefore increased from 30 to 150 schools. While the data from this sample form part of the overall South African findings, this methodology also allows for the Gauteng findings to be reported separately as a self-standing entity called a benchmarking participant in the TIMSS 2019 International Results in Mathematics and Science Report[8]. The Western Cape province also participated as a benchmarking participant in 2019.

The key research questions informing the analysis of the Gauteng province Grade 9 TIMSS 2019 data in this report are:

- What were the mathematics and science achievements, and achievement gaps, in TIMSS 2019 in Gauteng?
- What were the mathematics and science achievement trends from 2011 to 2019 in Gauteng?
- What factors were related to mathematics and science achievement in Gauteng?

The TIMSS Conceptual Framework

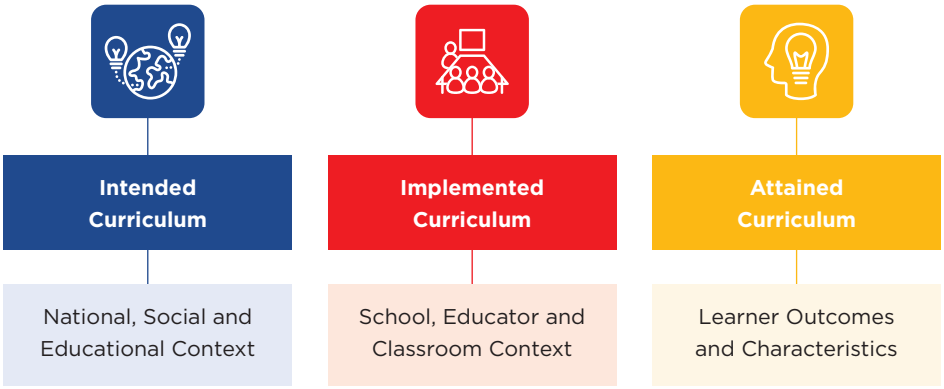
TIMSS uses the curriculum as the key organising concept to evaluate how education opportunities are provided to learners, and the factors that influence how learners use these opportunities. There are three key aspects to the TIMSS Curriculum Model: the intended curriculum, the implemented curriculum, and the attained curriculum (Mullis & Martin, 2017) (Figure 3).

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 3: The TIMSS Curriculum Model



8 https://timss2019.org/reports/

The TIMSS Assessment Framework

The TIMSS 2019 Assessment Framework[9] (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 provided in Chapter Four of this report.

What did Grade 9 Gauteng participants do in TIMSS 2019?

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

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. Each booklet contains two item blocks per subject (mathematics and science) and comprises both multiple choice and constructed items. There are a total of 14 booklets, but each learner completes only one of these booklets. Item blocks provide a mechanism through which to link learners' responses from the various booklets.

The TIMSS achievement booklets contain both trend and non-trend items. The trend items form an anchor that allows for estimating achievement over time. The non-trend items are new items generated for each cycle. For more details on the assessment frameworks and matrix design refer to the TIMSS 2019 Assessment Frameworks[10].

The contextual questionnaires

To obtain greater insight and identify possible explanations for achievement scores, TIMSS includes a set of contextual questionnaires. These contextual, or background, questionnaires are nationally adapted by each country. Adaptations includes both language editing, e.g. changes to spelling; as well as the inclusion of context-relevant questions, e.g. the language spoken at home by the learner in multilingual nations. Four background questionnaires were administered at Grade 9:

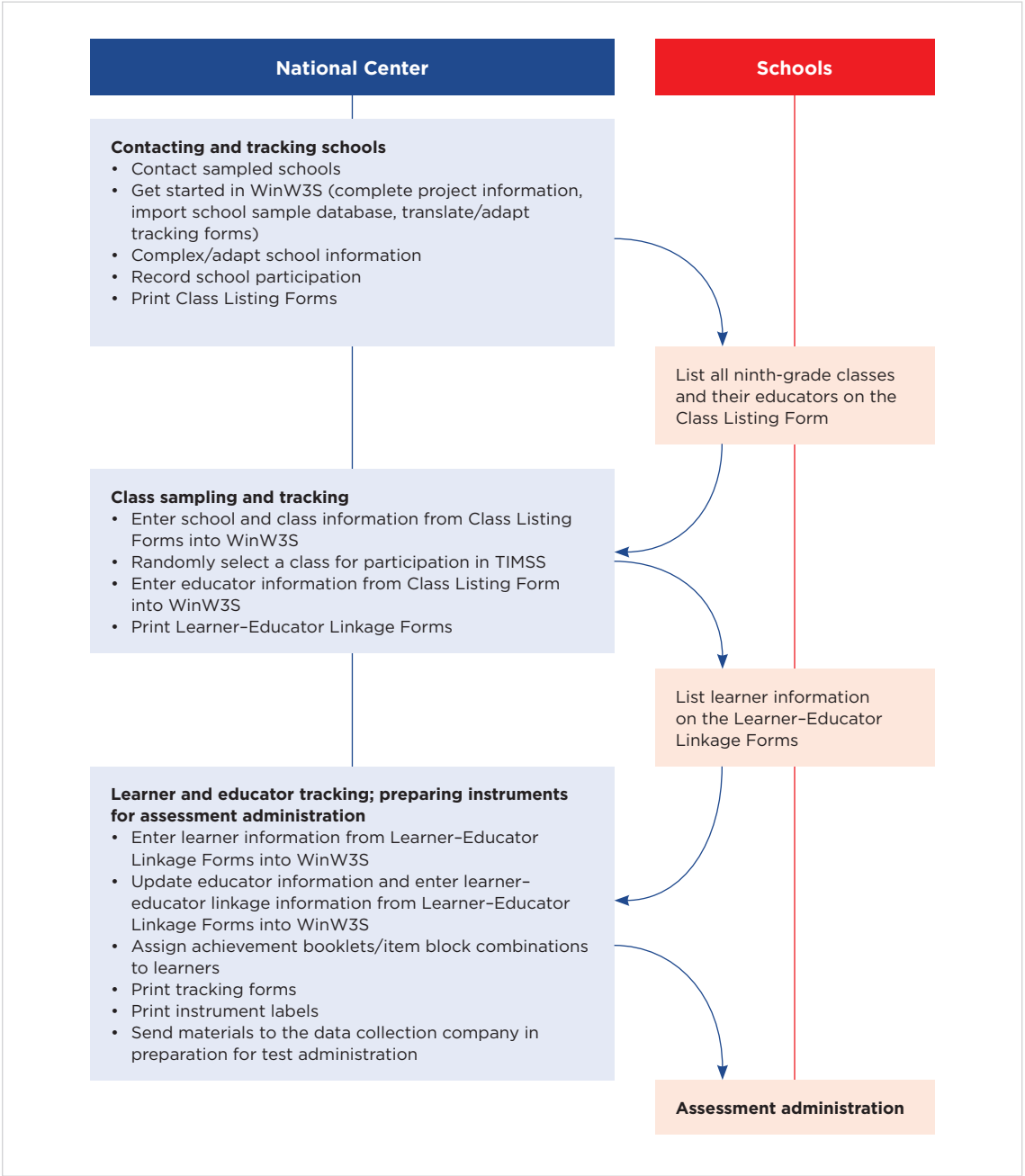
- The **Learner Questionnaire** asks about aspects of the learners' home and school lives, their home environment, their school climate for learning, and their perceptions and attitudes towards mathematics and science.
- The **Educator Questionnaire** is completed by both the mathematics and science educators of the participating learners. The questionnaire gathers information on educator characteristics, pedagogical practices, and the classroom context for teaching and learning.
- The **School Questionnaire** is completed by the principal in each of the sampled schools. It asks about school characteristics such as instructional time, available resources and technology, and school climate, as well as parental involvement.
- The **Curriculum Questionnaire** is completed by the National Research Coordinator, who gathers information pertaining to the curriculum followed by South African, and by implication Gauteng, schools. Information from the Curriculum Questionnaire is largely reported in the TIMSS 2019 Encyclopedia[11].

9 https://timssandpirls.bc.edu/timss2019/frameworks/
10 https://timssandpirls.bc.edu/timss2019/frameworks/
11 https://timssandpirls.bc.edu/timss2019/encyclopedia/

TIMSS pre-administration and administration

Each participating country and benchmarking entity 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[12] (Mullis, von Davier & Mullis, 2020). Figure 4 provides a map for the sampling procedures and logistical preparation to administer TIMSS in classrooms (further details are provided in Annexure 1).

Figure 4: TIMSS sampling procedures and preparations for the assessment administration



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

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

Selecting schools and learners

Statistics Canada selected a representative sample of Gauteng schools offering Grade 9 classes. TIMSS 2019 followed the sampling procedures described in the TIMSS 2019 Methods and Procedures Manual[13]. In most countries or benchmarking participants, a sample of 150 schools and one classroom in each school were selected, resulting in a sample of about 4 500 learners.

In Gauteng and the Western Cape, a sample of 150 schools was drawn. In the other seven provinces, the sample size was around 30 schools. The national samples were weighted so that each province contributed their appropriate share to estimate the national score while still ensuring that the Gauteng data were generalisable to the population of Grade 9 learners in the province.

In the two-stage stratified cluster sampling design, schools were randomly selected at the first stage and an intact Grade 9 class was selected at the second stage. 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 and Gauteng samples. The national sample was explicitly stratified by province and type of school (public and independent schools), and implicitly stratified by school quintile (refer to Reader's Guide). Schools in the sampling frame were those that offered Grade 9 classes and had no missing information on the stratification variables. From this sampling frame, a representative sample of 150 schools was drawn for Gauteng. In addition to the sample of participating schools, a first and second replacement school were selected to be used should a school have refused to participate.

Second stage: Schools selected in the first stage then submitted a list of all Grade 9 classes in the school to the HSRC. From these lists, an intact class was randomly selected using sampling software, WinW3S, provided by the IEA. Generally, one class per school was randomly selected. Following sampling, the WinW3S software 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 Gauteng sample is shown in Table 1.

Table 1: Gauteng designed and achieved school and learner samples

Sampled schools	Participating schools (N)	Participating learners (N)	Participating mathematics educators	Participating science educators	Participating principals
150	150	5 633	150	150	150

Reporting TIMSS achievement scores

As noted earlier, TIMSS 2019 employed a matrix sampling approach to create learner achievement booklets, where learners completed only a subset of the total TIMSS assessment: approximately 70 items, across mathematics and science. Due to this, Item Response Theory (IRT; refer to Reader's Guide) 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 were rounded to one decimal place.

13 https://timssandpirls.bc.edu/timss2019/methods/index.htm

Structure of the report

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

Chapter 1 framed the TIMSS 2019 in Gauteng. We outlined key policy elements of relevance to Gauteng and the TIMSS design and methodology.

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

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 learners and their home environments, and learner attitudes towards mathematics and science, respectively.

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

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

Chapter 10 concludes with the key findings and implications for the Gauteng province from TIMSS 2019.

SECTION B
ACHIEVEMENT AND ACHIEVEMENT GAPS

Thirty-nine countries and seven regional entities, called benchmarking participants, participated in the Grade 8 or 9 TIMSS 2019 assessments. Participating as a benchmarking province or city, provides an opportunity for this entity to assess the comparative international standing of their learners' achievement, and the identification of factors that explain achievement can inform local authorities on designing appropriate interventions.

Most countries participated at the eighth grade level whereas Norway and South Africa, as well as the Gauteng and Western Cape provinces, participated at the ninth grade level. More than half of the participating countries administered the computerised version of TIMSS (e-TIMSS) while the rest administered a paper version. The paper version was administered in South Africa and in Gauteng.

TIMSS describes performance in two ways: The first is through the achievement scale score, while the second is by characterising learners as having reached a set of international achievement benchmarks (refer to Reader's Guide). This section reports Gauteng Grade 9 learners' achievement in TIMSS 2019 and identifies achievement gaps in mathematics (Chapter 2) and science (Chapter 3).

Drawing from the *TIMSS 2019 International Results in Mathematics and Science* (Mullis et al., 2020), each chapter first summarises the average scale scores for each of the participating countries and benchmarking entities, including Gauteng. We then present the Gauteng mathematics and science achievement trend from 2011 to 2019, and achievement comparisons with other South African provinces. We also discuss Gauteng learners' performance in relation to the international achievement benchmarks.

The second part of each chapter is informed by HSRC analyses in describing scale scores by a locally relevant variable viz. socioeconomic status (SES) of schools. We end the section with a summary of key results.

CHAPTER TWO

MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

Numerical, mathematical and analytical skills are key for participation as citizens in a modern society, and as workers in the expanding knowledge and digitally dependent economies. Mathematics achievement at school is a signal of the ability of learners to continue studying mathematics, science and other technical subjects beyond school, to develop the competencies required by the contemporary workplace, and to participate in society as engaged citizens. Learners with sound mathematical skills can participate in higher-level cognitive reasoning and problem-solving tasks. Higher mathematical skills therefore allow an individual more freedom and opportunities in society and the labour market.

2.1. MATHEMATICS ACHIEVEMENT

Mathematics achievement in an international context

The Gauteng province participated as a benchmarking entity in TIMSS 2019, and we can thus report more reliable achievement estimates for this South African province. Figure 5 presents the average mathematics scale score with standard errors for the countries, as well as the Gauteng and Western Cape provinces, that participated in the eighth and ninth grade assessments. The figure also shows the scale score distribution underlying the average scale score. In addition, we present the scale score range within each country by calculating the difference between the 5th and 95th percentiles.

The countries and benchmarking entities are arranged from highest to lowest mathematics scale score. Five East Asian countries had the highest mathematics achievement, with Singapore, Chinese Taipei and Korea performing similarly. These countries were followed by Japan and Hong Kong. The five lowest performing countries were Oman, Kuwait, Saudi Arabia, South Africa and Morocco.

Gauteng Grade 9 learners scored an average of 421 TIMSS points in mathematics, significantly higher than the South African average of 389 points. The average scale scores of Gauteng, Jordan and Egypt were not significantly different from each other. Gauteng achieved significantly higher scores than Oman, Kuwait, Saudi Arabia, South Africa, and Morocco and significantly lower scores than the remaining participants, including Lebanon and the Western Cape (South African province).

The achievement inequality within countries (i.e. score difference between the 5th and 95th percentile) ranged from 224 points to 355 points. Of the set of 41 participants, there were 28 participants, including Gauteng, where the achievement inequality was less than 299 points and 13 participants with an achievement inequality greater than 300 points.

TIMSS achievement scale score

Each learner responds to only a subset of the 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 correctly, as well as the difficulty level of the items.

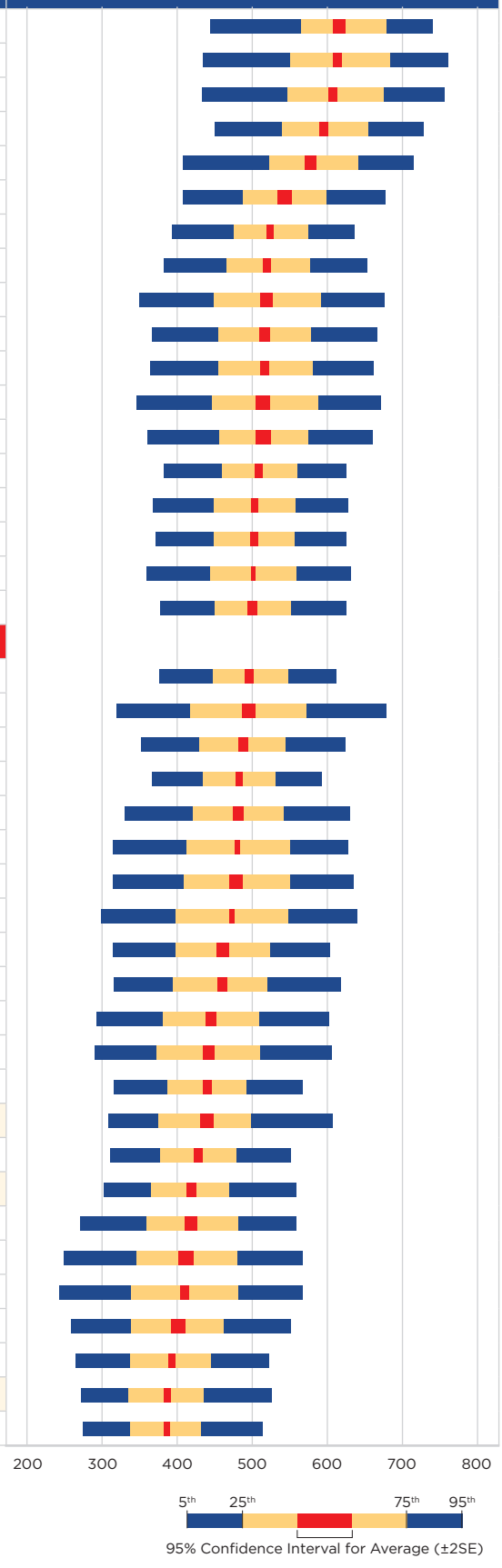
Learners complete their allocated assessment items and their scores on these items are combined with the demographic background of similar learners to calculate estimated scores for the full assessment. Five estimates, or plausible values, for each learner are drawn.

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 the term scale score to refer to learner achievement.

Figure 5: Average mathematics scale score and distribution, by country and benchmarking entity

Country	Average Scale Score	(SE)	Score difference between 5th and 95th percentiles
Singapore	616	(4.0)	294
Chinese Taipei	613	(2.7)	324
Korea, Rep. of	607	(2.8)	320
Japan	594	(2.7)	276
Hong Kong, SAR	578	(4.1)	304
Russian Federation	543	(4.6)	267
Ireland	524	(2.6)	241
Lithuania	520	(2.9)	268
Israel	519	(4.3)	322
Australia	517	(3.8)	297
Hungary	517	(2.9)	295
United States	515	(4.8)	323
England	515	(5.3)	297
Finland	509	(2.6)	241
Norway (9)	503	(2.4)	256
Sweden	503	(2.5)	252
Cyprus	501	(1.6)	269
Portugal	500	(3.2)	243
TIMSS Scale Centrepoint	**500**		
Italy	497	(2.7)	233
Turkey	496	(4.3)	355
Kazakhstan	488	(3.3)	269
France	483	(2.5)	224
New Zealand	482	(3.4)	297
Bahrain	481	(1.7)	311
Romania	479	(4.3)	318
United Arab Emirates	473	(1.9)	337
Georgia	461	(4.3)	286
Malaysia	461	(3.2)	299
Iran, Islamic Rep. of	446	(3.7)	307
Qatar	443	(4.0)	313
Chile	441	(2.8)	250
Western Cape, RSA (9)	**441**	**(4.4)**	**295**
Lebanon	429	(2.9)	238
Gauteng, RSA (9)	**421**	**(3.0)**	**253**
Jordan	420	(4.3)	284
Egypt	413	(5.2)	315
Oman	411	(2.8)	321
Kuwait	403	(5.0)	290
Saudi Arabia	394	(2.5)	256
South Africa (9)	**389**	**(2.3)**	**252**
Morocco	388	(2.3)	237



Source: Mullis et al. (2020).

Reading a distribution or percentile graph

A percentile is a number between 1 and 99 where a certain percentage of scores fall below that number. The TIMSS distribution graphs are drawn from the 5th to the 95th percentile with the confidence interval (refer to Reader's Guide) 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 left-outer section (blue) of the bar covers the range between the 5th and 25th percentiles. The yellow section shows the range of scores between the 25th percentile and the lower limit of the confidence level for the average score. The right-hand side of the graph is read similarly, where the yellow section represents the scores between the upper limit of the confidence interval and the 75th percentile, and the right-outer section (blue) the scores between the 75th and 95th percentiles.

Gauteng in relation to countries with similar mathematics achievement scores

The average mathematics scale score of Gauteng learners was not significantly different from the countries of Jordan and Egypt. Gauteng did, however, achieve significantly higher scores than Oman and Kuwait, and significantly lower than Lebanon and the Western Cape. A comparison of this set of TIMSS participants could provide a more contextual perspective to explain Gauteng mathematics achievement. Table 2 presents the macro-indicators that could influence education outcomes among participants with achievement scores similar or close to Gauteng.

The characteristics of each of the compared educational systems were different: the population ranged from 4.2 million for Kuwait to 100 million for Egypt; the GDP per capita ranged from US$3 019 for Egypt to US$32 373 for Kuwait. The index of income inequality was highest for South Africa and its two participating provinces (Gauteng and the Western Cape). South Africa and Egypt had the lowest Human Development Index (HDI). Interestingly, the index of income inequality for Egypt was much lower than for the South African provinces, but their achievement inequality was much higher. We cannot explain achievement by any single indicator but need to consider the interaction of these indicators and their influence on achievement.

Table 2: Mathematics scale scores and key macro-indicators of countries and entities with similar scores to Gauteng

	Average math scale score (SE)	Population (millions)	Net/gross[i] enrolment primary	Net/gross[i] enrolment secondary	GDP per capita (US$) (2019)[iv]	Index of income inequality	HDI (2019)[vi]	Achievement inequality (5th to 95th percentile)
Western Cape	441 (4.4)	6.8	119[ii]	85[ii]	7 340[v]	58.0	0.745	295
Lebanon	429 (2.9)	6.9	89[iii]	61[iii]	7 578	31.8	0.744	238
Gauteng	421 (3.0)	15.2	116[ii]	103[ii]	8 355[v]	62.0	0.730	253
Jordan	420 (4.3)	10.1	81	63	4 405	33.7	0.729	284
Egypt	413 (5.2)	100.4	97	83	3 019	31.5	0.707	315
Oman	411 (2.8)	5.0	86	96	17 701	-	0.813	321
Kuwait	403 (5.0)	4.2	83	87	32 373	-	0.806	290
South Africa	389 (2.3)	58.6	87	72	6 153[v]	63.0	0.709	252

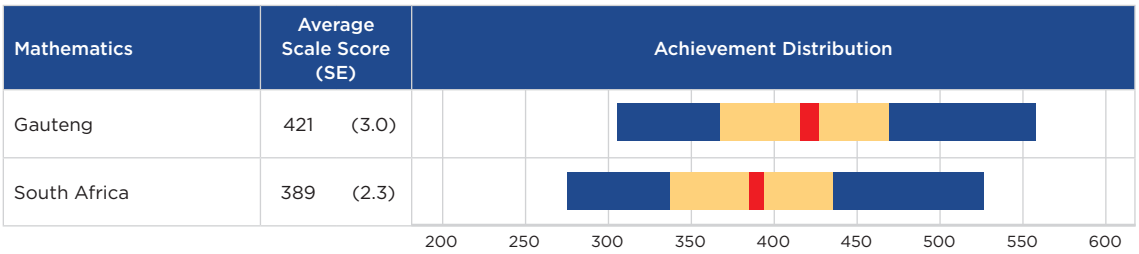
i The figures for the Western Cape, Lebanon and Gauteng are Gross Enrolment Rate (GER) while the rest of the figures are Net Enrolment Rate (NER).
ii The primary and secondary enrolment percentage for Gauteng and the Western Cape refers to GER. From *Education Series Volume III: Educational Enrolment and Achievement*, by Statistics South Africa, 2016c.
iii The primary and secondary enrolment percentage for Lebanon refers to GER. From https://tinyurl.com/33txsta4, by Knoema, retrieved 24 March 2022.
iv From https://data.worldbank.org/indicator/NY.GDP.PCAP.CD, retrieved 05 May 2022.
v From https://www.statssa.gov.za/?p=12056, *Four Facts About Our Provincial Economies*, StatsSA (2017), retrieved 05 May 2022. Converted to US Dollar using the average US Dollar to South African Rand exchange rate in 2017.
vi From https://globaldatalab.org/shdi/, retrieved 23 March 2022.

Gauteng mathematics achievement and learners reaching international achievement benchmarks

Figure 6 presents the average mathematics achievement, at the ninth grade, for Gauteng and South Africa, together with the scale score distribution.

The average mathematics scale score of Gauteng learners was **421 (3.0)**, significantly higher than the average scale score for South Africa of 389 (2.3). In the province, 253 TIMSS points separated the 5th and 95th percentiles, which is approximately mid-range in comparison to other participating countries and similar to the achievement inequality for South Africa (252 points). Therefore, while the average mathematics achievement in Gauteng was higher than the South African average achievement score, the province still struggled with the same levels of inequality as the country as a whole.

Figure 6: Average Gauteng province and South African mathematics achievement and scale score distribution



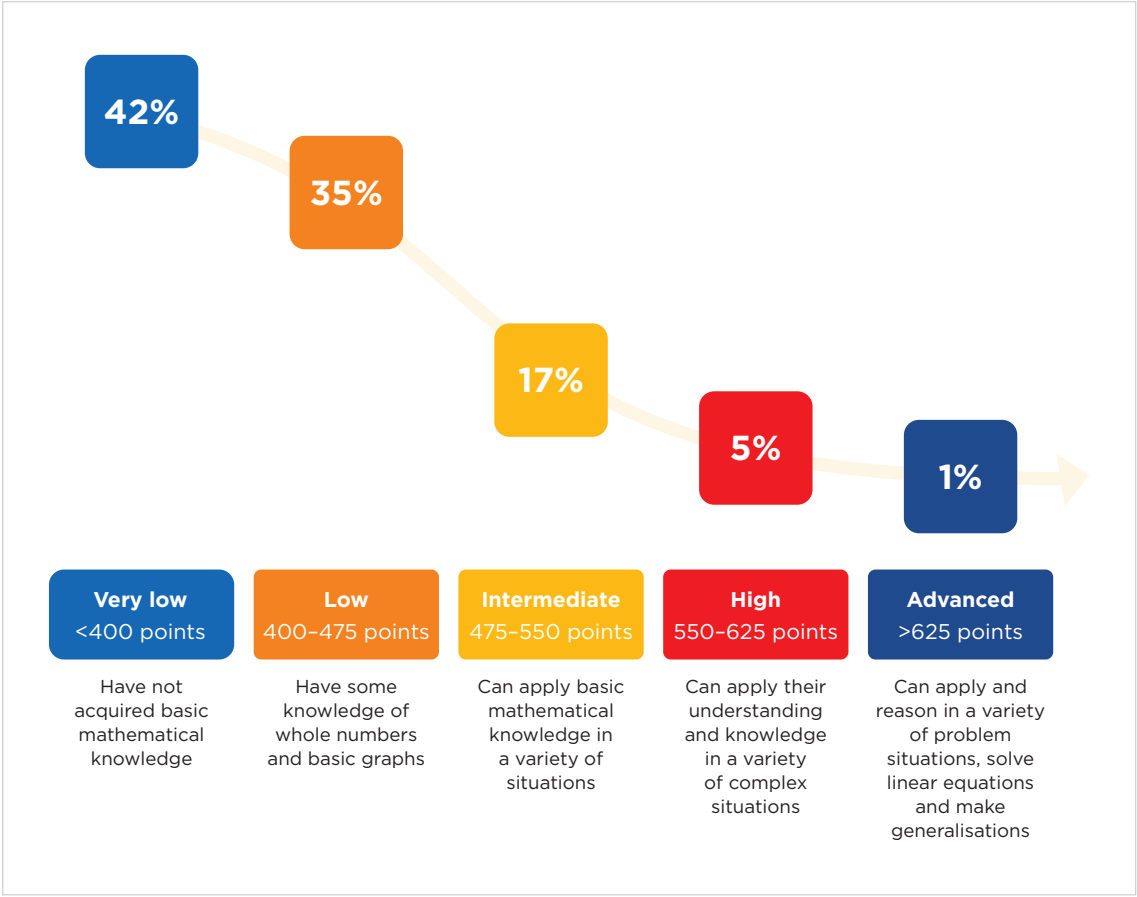
Source: TIMSS 2019 South African Grade 9 dataset.

Further insight into learner achievement is derived from reviewing 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 scores less than 400 points.

Figure 7 provides the percentage of Gauteng Grade 9 learners who reached each of the international achievement benchmarks for mathematics. The figure also presents the scale score range associated with each benchmark and a brief description of the abilities that learners would demonstrate at each of these points.

Figure 7: Percentage of Gauteng learners reaching mathematics international achievement benchmarks



Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Cumulatively, 58 percent of Gauteng Grade 9 learners demonstrated that they had acquired basic mathematical knowledge, achieving 400 TIMSS points or higher. In contrast, 42 percent of learners did not exhibit basic mathematical knowledge which indicates that the province still has a way to go to improve. It is, however, noteworthy that cumulatively six percent of Gauteng learners achieved at the highest levels, with scale scores higher than 550 TIMSS points. The comparative statistic for countries with similar achievement scores to Gauteng were Jordan (6%) and Egypt (8%), while 13 percent of Western Cape learners achieved at the higher international benchmarks.

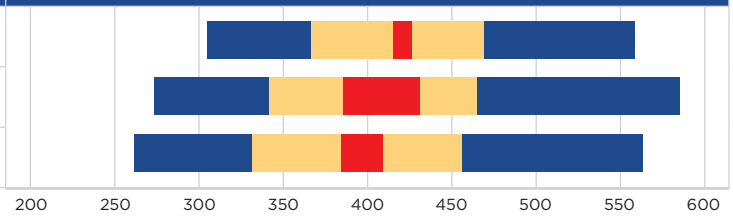
In subsequent analyses, we combined the *High* and *Advanced International Benchmarks* and use the term 'High International Benchmark' to describe all achievement above 550 points.

Trends in mathematics achievement in Gauteng (TIMSS 2011 to 2019)

Gauteng participated, with a sample of around 30 schools, as part of the South African TIMSS sample in the previous rounds of the study. These provincial achievement estimates were less precise, with large standard errors and confidence intervals. In Figure 8, we compare Gauteng's achievements from 2011 to 2019, with the caveat that 2011 and 2015 estimates had higher standard errors.

Figure 8: Average Gauteng mathematics achievement and scale score distributions from 2011 to 2019

Mathematics	Average Scale Score (SE)	Achievement Distribution
TIMSS 2019	421 (3.0)	
TIMSS 2015	408 (11.4)	
TIMSS 2011	397 (6.3)	



Source: TIMSS 2011, 2015 and 2019 South African (Gauteng) Grade 9 datasets.

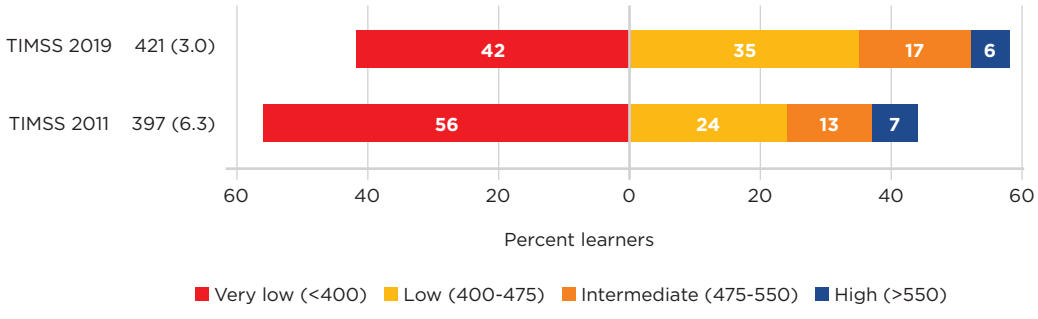
Between TIMSS 2011 and 2019, the Grade 9 mathematics achievement score for Gauteng increased from 397 to 421 points, a statistically significant (refer to Reader's Guide) increase of 24 points. The average achievement improvement rate from 2011 to 2019 was therefore three TIMSS points per year for Gauteng, compared with an average improvement of 4.6 TIMSS points per year for South Africa.

Closer examination of the achievement distribution between the 5th and 95th percentile (the length of the bars in Figure 8) for 2011 to 2019, shows that better gains were achieved at the lower end of the achievement distribution, meaning that those learners with lower achievement, generally from the poorest households, had improved the most. Improvement by these learners may explain the slight narrowing of the achievement distribution over time, suggesting decreasing achievement inequality.

In line with increases in mathematics achievement from 2011 to 2019, the mathematics ability levels of learners also improved (Figure 9)[14]. The percentage of learners demonstrating abilities at the different TIMSS achievement benchmarks increased over this period. In 2011, 44 percent of learners scored above 400 TIMSS points, demonstrating that they had attained minimum mathematical abilities. This increased to 58 percent in the 2019 cycle.

Gauteng improved its educational achievement between 2011 and 2019 – improving achievement scores at the lower end of the achievement scale. However, the province did not show much improvement among its higher performing learners. The questions for the province are, thus, whether these improvements are enough to meet both its developmental and labour market needs, and how can improvement at the higher end of the distribution be fostered?

Figure 9: Average mathematics scale score and percentage of Gauteng learners reaching international achievement benchmarks from 2011 to 2019



Source: TIMSS 2011 and 2019 South African (Gauteng) Grade 9 datasets.

14 The percentage of learners to the right of the 0 point had acquired the basic knowledge and skills for Grade 9, while the percentage of learners to the left of the 0 point had not acquired basic mathematics knowledge and skills.

Mathematics achievement of Gauteng learners relative to other provinces

Using the South African Grade 9 TIMSS 2019 dataset, Table 3 provides the achievement comparison between provinces and highlights whether the difference was statistically higher or lower, or where there was no significant difference from the comparison province[15].

The top three performing provinces for mathematics in 2019 were the Western Cape with an average scale score of 441 (4.4), Gauteng with 421 (3.0), and Free State with 396 (5.5). The Gauteng mathematics achievement score was significantly lower than the Western Cape score and significantly higher than all other provinces.

Table 3: Average provincial mathematics scale score and comparison between provinces

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

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

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

2.2. MATHEMATICS ACHIEVEMENT GAPS

In an ideal world, achievement gaps should only reflect differences in the abilities and efforts of learners. But in most educational systems, the achievement gaps that exist are associated with a number of contextual factors. Thus, a single provincial achievement score does not tell the full story of learners' performance in Gauteng. Rather, better insights are provided through a more nuanced achievement story reported by the SES of the school (school quintile and fee-status of the school).

Mathematics achievement and ability levels by socioeconomic status of the school

Gauteng schools vary in relation to the area in which they are located and their access to infrastructure and resources. To address these imbalances, the DBE has calculated a poverty index for each public school according to the income, literacy and unemployment levels in the community around the 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 better resourced schools in more affluent communities. Table 4 reports the average mathematics achievement for schools in each DBE defined quintile category and the comparisons between them, as well as for independent schools[16].

15 For a full analysis of achievement and achievement trends of all nine provinces, we refer the reader to the TIMSS 2019 Grade 9 National Report (cf. Reddy et al., 2022).

16 At the national level, we explicitly sample for independent schools. We did not do so in the Gauteng provincial sample. We included the average scores for independent schools as it constituted 11 percent of the learner sample and 16 sampled schools. This should be considered indicative rather than representative scores.

The average mathematics achievement for learners in Quintile 1, 2 and 3 schools were similar, with no significant differences between them. The average mathematics achievement of learners in Quintile 4 schools (408 points) was significantly higher than that of Quintile 1, 2 and 3 schools but significantly lower than that of Quintile 5 and independent schools. Quintile 5 and independent schools did not have significant differences between their scores. However, neither of these more resourced school types reached the TIMSS centrepoint of 500 TIMSS points.

Table 4: Average Gauteng mathematics scale score, by school quintile rank and comparisons

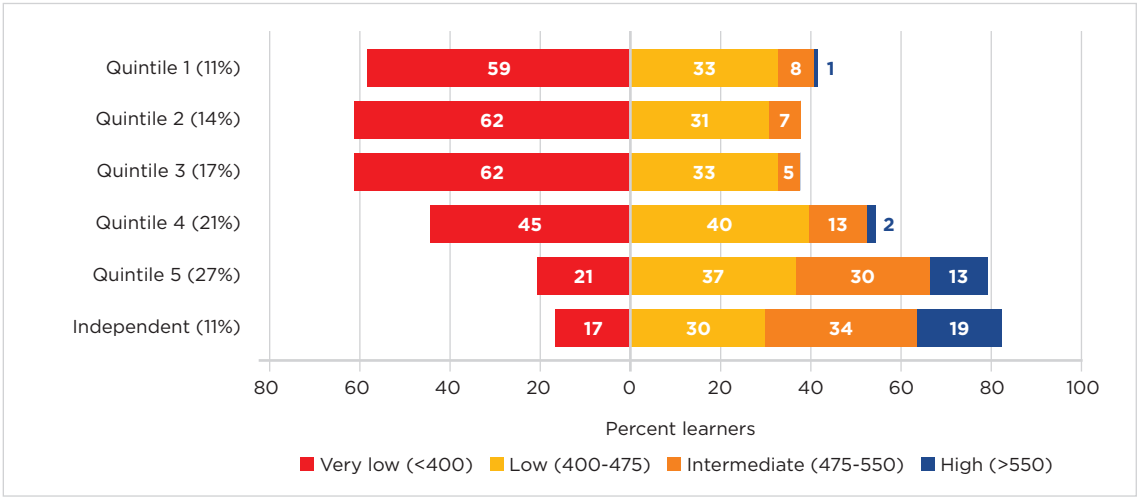
		Comparison quintile					
Quintile Rank	Average Gauteng Mathematics Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	479 (9.8)			▲	▲	▲	▲
Quintile 5	462 (7.8)			▲	▲	▲	▲
Quintile 4	408 (5.5)	▽	▽		▲	▲	▲
Quintile 3	385 (4.8)	▽	▽	▽			
Quintile 2	383 (5.6)	▽	▽	▽			
Quintile 1	388 (7.3)	▽	▽	▽			

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

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

When the achievement scale scores of each quintile are described in terms of ability levels, Figure 10 reveals a contrast between achievement patterns of learners in the different school quintiles and in independent schools. In Quintile 1 to 3 schools three in five learners had not acquired basic mathematical knowledge and skills for the grade (i.e. scoring below the *Low International Benchmark* of 400 TIMSS points). The corresponding figure in Quintile 4 schools was 45 percent. In Quintile 5 and independent schools, on average 20 percent of learners had not acquired the basic knowledge and skills. Thirteen percent of learners in Quintile 5 schools achieved above the *High International Benchmark* of 550 TIMSS points, with the corresponding figure of 19 percent in independent schools. These learners possess the ability to apply mathematical knowledge and understanding in complex situations.

Figure 10: Percentage of Gauteng mathematics learners reaching international benchmarks, by school type (% learners)



Source: Authors' own calculations from TIMSS 2019 South Africa (Gauteng) Grade 9 dataset.

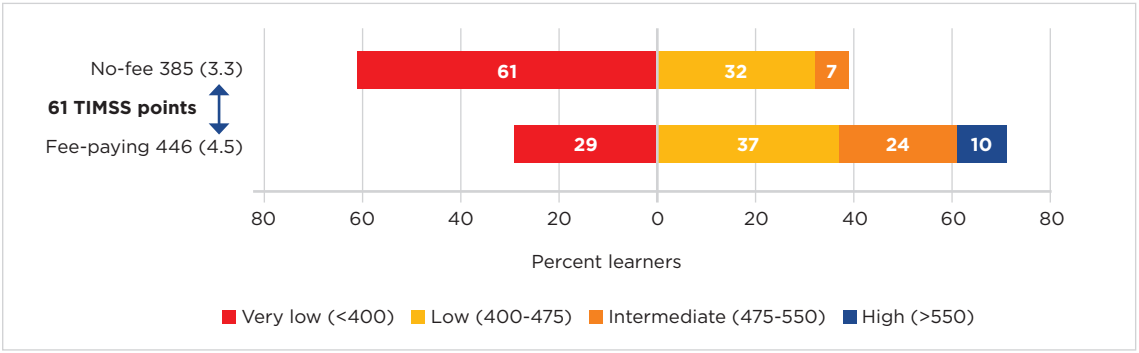
Mathematics achievement and ability levels by school fee status

With the high levels of household poverty in the country, the amended South African Schools Act (RSA, 1996c) legislated the abolition of fees for learners attending schools in poorer communities. The national government fully subsidises the school fees for learners in Quintile 1, 2 and 3 schools, which are called 'no-fee' schools[17]. Learners in Quintile 4 and 5 and independent schools pay fees, and their schools are designated as 'fee-paying'.

As expected, the differences in the material school and home conditions for learners attending no-fee and fee-paying schools lead to unequal achievements. Figure 11 describes the average mathematics achievement and percentage of learners reaching the different international achievement benchmarks by school fee status. The average mathematics score for learners in no-fee schools was 385 (3.3), similar to the national average, and in fee-paying schools it was 446 (4.5). This means a mathematics achievement gap of 61 TIMSS points between learners attending no-fee and fee-paying schools.

When the achievement scale scores are described in terms of ability levels 71 percent of learners in fee-paying schools demonstrated that they had acquired basic mathematical knowledge and skills. In no-fee schools, 39 percent of learners showed that they had acquired basic mathematical knowledge and skills. This means that 61 percent of Gauteng Grade 9 learners in no-fee schools had not acquired the basic knowledge and skills for that grade.

Figure 11: Average mathematics scale score and percentage of Gauteng learners reaching international achievement benchmarks, by school fee status



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

The following section provides a summary of Gauteng Grade 9 learners' mathematics achievement and achievement gaps that existed in TIMSS 2019.

17 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 more resourced communities, and attend schools with better qualified educators and a climate that promotes better teaching and learning.

2.3. SUMMARY: MATHEMATICS ACHIEVEMENT AND ACHIEVEMENT GAPS

Mathematics performance

The Gauteng average achievement score was in the lowest quarter of the set of TIMSS 2019 participating countries and entities. The Gauteng average mathematics scale score of 421 (3.0) was significantly higher than the South African average mathematics score and similar to the scores for Jordan and Egypt.

Fifty-eight percent of learners had acquired basic mathematical knowledge and skills, and six percent achieved at the higher TIMSS achievement benchmarks, scoring over 550 points and thus demonstrated that they could solve complex problems.

The Gauteng mathematics achievement inequality was 253 TIMSS points.

Trends in Gauteng mathematics achievement

Provincial achievement trends are cautiously interpreted because of smaller sample sizes in previous TIMSS cycles. Between 2011 and 2019, the Gauteng mathematics achievement score increased from 397 to 421 points, a statistically significant increase of 24 points. The average improvement rate was three points per year.

During the same period, the share of learners who acquired basic mathematical knowledge increased from 44 percent in 2011 to 58 percent in 2019.

The best achievement gains were from the lowest performing learners.

Gauteng mathematics achievement in relation to other provinces

Gauteng was the second highest performing province in South Africa, achieving significantly lower mathematics scores than Western Cape province, but significantly higher than all other provinces.

Mathematics performance by socioeconomic status of the school

The average mathematics achievement scores for learners in Quintile 1, 2 and 3 schools were not statistically different. Learners in Quintile 4 schools achieved significantly higher scores than learners in Quintile 1, 2 and 3 schools but significantly lower than those of Quintile 5 and independent schools.

The average mathematics achievement scores for Quintile 5 and independent schools were not statistically different. While they outperformed all other quintiles, they did not reach the TIMSS centrepoint of 500 TIMSS points.

Close to 40 percent of learners in Quintile 1, 2 and 3 schools; 55 percent in Quintile 4 schools and 80 percent in Quintile 5 and independent schools demonstrated that they had acquired basic mathematical knowledge and skills.

The average mathematics score for Gauteng learners in no-fee schools was 385 (3.3), compared to 446 (4.5) in fee-paying schools. The mathematics achievement gap between learners in no-fee and fee-paying schools was 61 TIMSS points.

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

CHAPTER THREE

SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Science learning involves the application of knowledge and understanding of the natural and social world, following a systematic methodology based on evidence. It is considered an important area of education in any country, as it contributes to increased science and technology knowledge, increases scientific development in higher education and other related fields, and scientific knowledge has both an economic and cultural significance. Learning science also has other benefits for learners such as improved problem-solving, critical thinking, and perseverance skills.

3.1. SCIENCE ACHIEVEMENT

Science achievement in an international context

Gauteng participated as a benchmarking entity in TIMSS 2019 at Grade 9 and we are thus able to report more reliable achievement estimates for this South African province. Figure 12 presents the average science scale score with standard errors (SE) for countries and the two South African provinces that participated in the eighth and ninth grade assessments, together with the scale score distribution underlying the average scale score. In addition, we present the scale score range within each country by calculating the difference between the 5th and 95th percentiles.

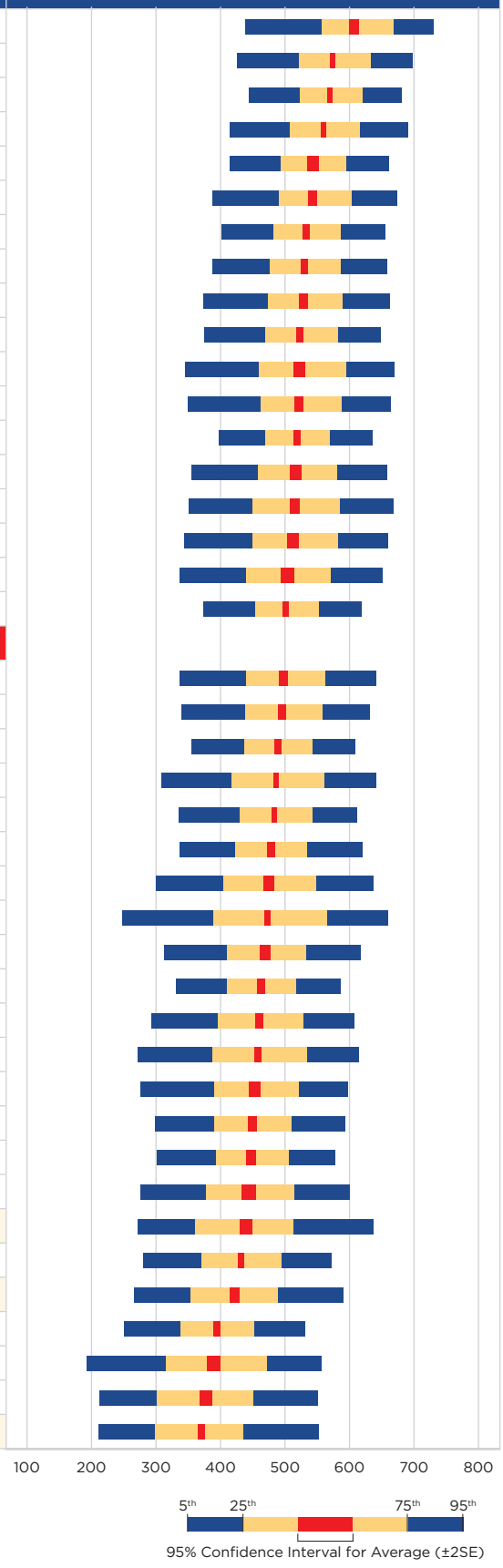
The countries are arranged from highest to lowest scale score. Singapore had the highest science achievement, followed by three other East Asian countries – Chinese Taipei, Japan, and Korea – who performed similarly. The fifth highest scoring country was the Russian Federation. The five lowest performing countries or benchmarking entities were Gauteng, Morocco, Egypt, Lebanon and South Africa.

The science achievement average for Gauteng of 422 TIMSS points was significantly higher than the South African average of 370 TIMSS points. The average science scale score of Gauteng and benchmarking participant Abu Dhabi were not significantly different. Gauteng significantly outperformed Morocco, Egypt, Lebanon and South Africa, but scored significantly lower than all other participants, including the other South African benchmarking participant, the Western Cape.

The achievement inequality (difference between the 5th and 95th percentile scores) within countries ranged from 237 to 413 TIMSS points. Of the set of 41 participants, there were 21 participants where the achievement inequality was between 237 and 299 points, and 18 entities, including Gauteng, with an achievement inequality greater than 300 points. Participating countries and benchmarking entities with the highest achievement inequality were the United Arab Emirates (difference of 413 points), Egypt (366 points) and Oman (343 points); while those with the lowest achievement inequality were Japan (237 points), Portugal (238 points) and Italy (246 points). For information on how to interpret percentile graphs please refer to the Reader's Guide.

Figure 12: Average science scale score and distribution, by country and benchmarking entity

Country	Average Scale Score	(SE)	Score difference between 5th and 95th percentiles
Singapore	608	(3.9)	291
Chinese Taipei	574	(1.9)	271
Japan	570	(2.1)	237
Korea, Rep. of	561	(2.1)	278
Russian Federation	543	(4.2)	247
Finland	543	(3.1)	285
Lithuania	534	(3.0)	254
Hungary	530	(2.6)	271
Australia	528	(3.2)	291
Ireland	523	(2.9)	274
United States	522	(4.7)	325
Sweden	521	(3.2)	315
Portugal	519	(2.9)	238
England	517	(4.9)	303
Turkey	515	(3.7)	318
Israel	513	(4.2)	318
Hong Kong, SAR	504	(5.2)	313
Italy	500	(2.6)	246
TIMSS Scale Centrepoint	**500**		
New Zealand	499	(3.5)	307
Norway (9)	495	(3.1)	292
France	489	(2.7)	254
Bahrain	486	(1.9)	334
Cyprus	484	(1.9)	277
Kazakhstan	478	(3.1)	283
Qatar	475	(4.4)	336
United Arab Emirates	473	(2.2)	413
Romania	470	(4.2)	304
Chile	462	(2.9)	256
Malaysia	460	(3.5)	316
Oman	457	(2.9)	343
Jordan	452	(4.7)	321
Iran, Islamic Rep. of	449	(3.6)	295
Georgia	447	(3.9)	275
Kuwait	444	(5.7)	324
Western Cape, RSA (9)	**439**	**(5.1)**	**366**
Saudi Arabia	431	(2.6)	291
Gauteng, RSA (9)	**422**	**(3.9)**	**324**
Morocco	394	(2.7)	280
Egypt	389	(5.4)	366
Lebanon	377	(4.7)	338
South Africa (9)	**370**	**(3.1)**	**341**



Source: Mullis et al. (2020)

Gauteng in relation to countries with similar science achievement scores

The average science scale scores of Gauteng Grade 9 learners were not significantly different from those of another benchmarking participant, Abu Dhabi. The achievement scores were significantly higher than for Morocco, Egypt and Lebanon and significantly lower than Saudi Arabia and the Western Cape. A comparison of this set of countries and benchmarking entities could provide a more contextual perspective to explain Gauteng science achievement. Table 5 illustrates the differences on macro-indicators that could influence education outcomes among TIMSS participants with achievement similar or close to Gauteng.

The characteristics of each of the educational systems being compared were different: the population ranged from 6.8 million for the Western Cape to 100 million for Egypt, with the GDP per capita ranging from $3 019 for Egypt to $ 23 140 for Saudi Arabia. The index of income inequality was highest for South Africa and its two participating provinces (Western Cape and Gauteng). There was no discernible pattern between the index of income inequality and achievement inequality. Morocco, Egypt and South Africa had the lowest Human Development Index (HDI)[18]. We cannot explain achievement by a single indicator but need to consider the interaction of these indicators and their influence on achievement.

Table 5: Gauteng science scale scores and key macro-indicators of countries with similar scores

	Average science scale score (SE)	Population (millions)	Net/gross[i] enrolment primary	Net/gross[i] enrolment secondary	GDP per capita (US$) (2019)[iii]	Index of income inequality	HDI (2019)[v]	Achievement inequality (5th to 95th percentile)
Western Cape	439 (5.1)	6.8	119[ii]	85[ii]	7 340[v]	58.0	0.745	366
Saudi Arabia	431 (2.6)	34.3	95	96	23 140	-	0.853	291
Gauteng	422 (3.9)	15.2	116[ii]	103[ii]	8 355[v]	62.0	0.730	324
Morocco	394 (2.7)	36.5	99	64	3 235	39.5	0.685	280
Egypt	389 (5.4)	100.4	97	83	3 019	31.5	0.707	366
Lebanon	377 (4.7)	6.9	89[iii]	61[iii]	7 578	31.8	0.744	238
South Africa	370 (3.1)	58.6	87	72	6 153[v]	63.0	0.709	252

i The Western Cape, Gauteng and Lebanon figures are Gross Enrolment Rates (GER) while all others are Net Enrolment Rates (NER)
ii The primary and secondary enrolment percentage for the Western Cape and Gauteng refers to GER. From *Education Series Volume III: Educational Enrolment and Achievement*, by Statistics South Africa, 2016c.
iii The primary and secondary enrolment percentage for Lebanon refers to GER. From https://tinyurl.com/33txsta4, by Knoema, retrieved 24 March 2022.
iv From https://data.worldbank.org/indicator/NY.GDP.PCAP.CD, retrieved 05 May 2022.
v From https://www.statssa.gov.za/?p=12056, *Four Facts About Our Provincial Economies*, StatsSA (2017), retrieved 05 May 2022. Converted to US Dollar using the average US Dollar to South African Rand exchange rate in 2017.
vi From https://globaldatalab.org/shdi/, retrieved 23 March 2022.

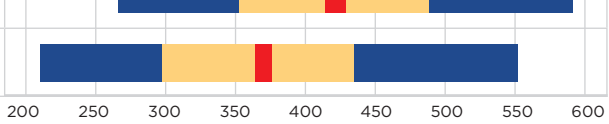
18 The Human Development Index is a composite index of life expectancy, education, and per capita income indicators.

Gauteng science achievement and learners reaching international achievement benchmarks

Figure 13 presents the average science achievement, at the ninth grade, for Gauteng and South Africa, together with the scale score distribution. The average science scale score of Gauteng Grade 9 learners was **422 (3.9)**. In the province, 324 points separated the 5th and 95th percentiles, providing a measure of the achievement inequality. In comparison, the average science scale score for South Africa was 370 (3.1), with a slightly wider score distribution of 341 points. The average science achievement in Gauteng was higher than the national average achievement score, but still struggled with the same levels of inequality as the country.

Figure 13: Average Gauteng province and South African science achievement and scale score distributions

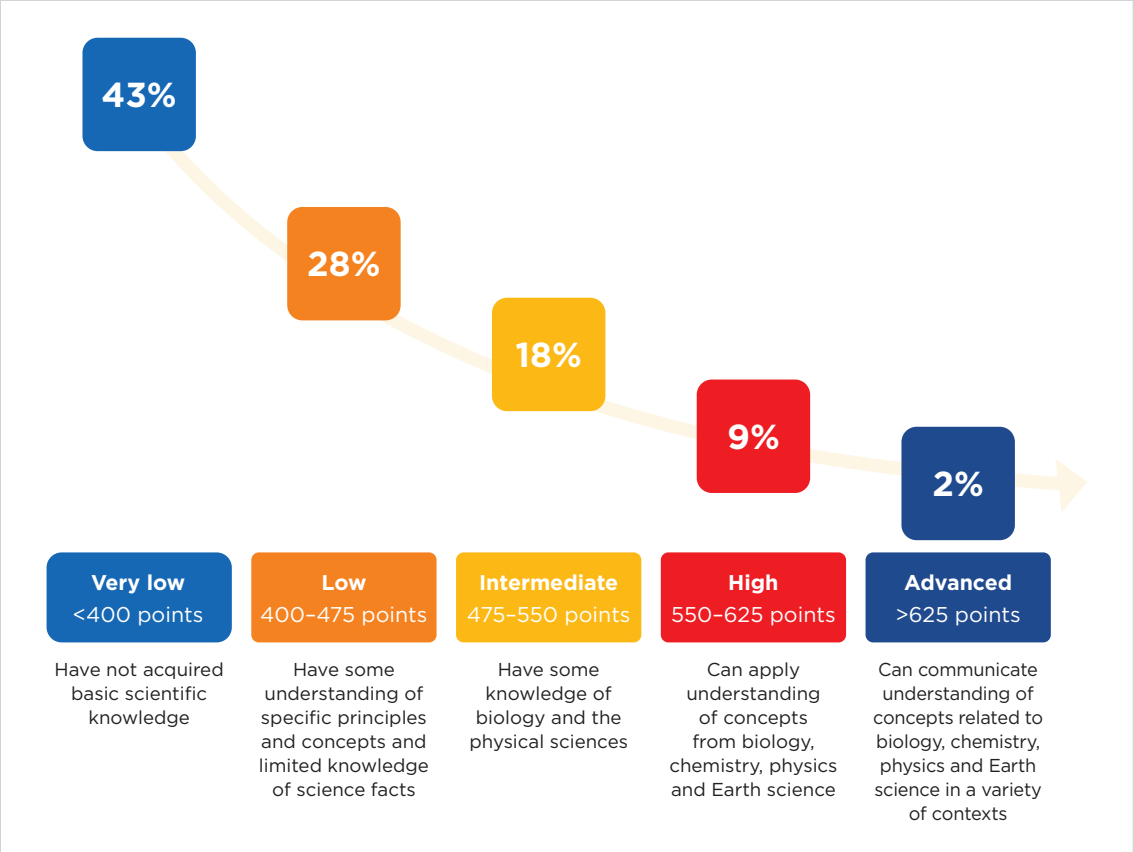
Science	Average Scale Score (SE)	Score difference between 5th and 95th percentiles	Achievement Distribution
Gauteng, RSA (9)	422 (3.9)	324	
South Africa (9)	370 (3.1)	341	



Source: TIMSS 2019 South African Grade 9 dataset.

Further insight into learner achievement is derived from describing their performance in relation to the TIMSS international achievement benchmarks. Figure 14 provides the percentage of Gauteng Grade 9 learners who reached each of the achievement benchmarks in TIMSS 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 14: Percentage of learners reaching science international benchmarks



Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Cumulatively, 57 percent of Gauteng learners demonstrated that they had acquired basic scientific knowledge by achieving 400 TIMSS points or higher. In contrast, 43 percent of learners did not exhibit mastery of basic scientific knowledge. The challenge is for the province to improve science achievement for the lowest performing learners.

It is, however, noteworthy that 11 percent of Gauteng science learners achieved at the highest levels with scale scores at or above 550 points. The comparative statistic for Abu Dhabi was 19 percent, while for Western Cape learners it was 17 percent.

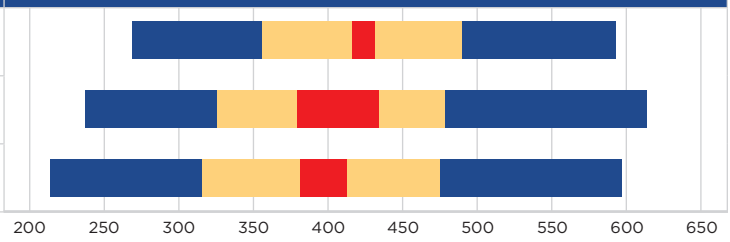
In subsequent analyses, we combined the *High* and *Advanced International Benchmarks* and use 'High International Benchmark' to describe all achievements above 550 points.

Trends in science achievement and achievement benchmarks in Gauteng (TIMSS 2011 to 2019)

Gauteng participated, with a sample of around 30 schools, as part of the South African TIMSS sample in previous rounds of the study. These provincial achievement estimates were less precise with larger standard errors and confidence intervals. In Figure 15 we compare the Gauteng achievements from 2011 to 2019, with the caveat that 2011 and 2015 estimates had higher standard errors.

Figure 15: Average Gauteng science achievement and scale score distributions from 2011 to 2019

Science	Average Scale Score (SE)	Achievement Distribution
TIMSS 2019	422 (3.9)	
TIMSS 2015	405 (13.8)	
TIMSS 2011	396 (7.6)	



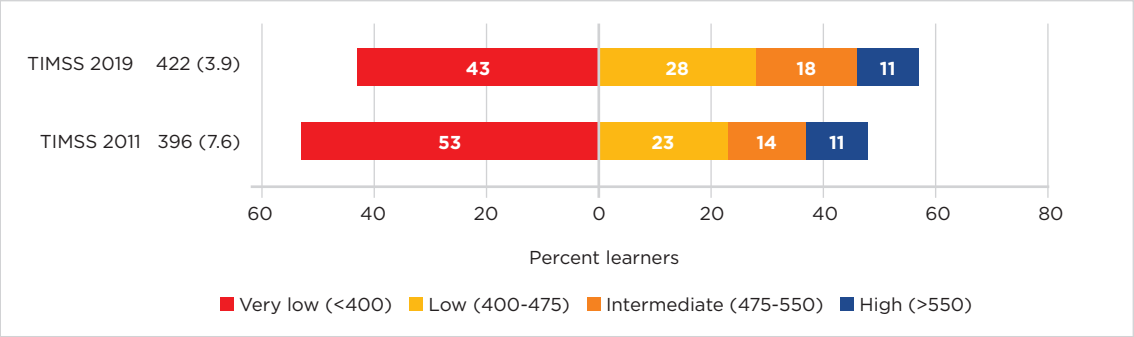
Source: TIMSS 2011, 2015 and 2019 South African (Gauteng) Grade 9 datasets.

Between 2011 and 2019, the science achievement increased from 396 to 422 TIMSS points, a statistically significant increase of 26 points. The average science achievement improvement rate from 2011 to 2019 was 3.3 points per year for Gauteng, compared with 4.8 points per year for South Africa.

Closer examination of the achievement distribution between the 5th and 95th percentile (the length of the bars in Figure 15) for 2011 to 2019 shows that the best gains were achieved at the lower end of the achievement distribution, meaning that those learners with lower achievement, generally from the poorer households, had improved the most. However, it is concerning that, since 2011, there has been very little improvement at the top end of the distribution.

In line with increases in science achievement from 2011 to 2019, the scientific ability levels of learners also improved (Figure 16). In 2011, just under half the learners (48%) scored above 400 TIMSS points, demonstrating that they had attained minimum scientific abilities. This increased to 57 percent in 2019.

Figure 16: Average science scale score and percentage of Gauteng learners reaching international benchmarks from 2011 to 2019



Source: TIMSS 2011 and 2019 South African (Gauteng) Grade 9 datasets.

Science achievement of Gauteng learners relative to other provinces

Using the South African TIMSS dataset, Table 6 provides the achievement comparison between provinces and highlights whether the difference was statistically higher, statistically lower, or where there was no significant difference from the comparison province[19].

The top three performing provinces for science were the Western Cape, with an average scale score of 439 (5.1), Gauteng with 422 (3.9), and Free State with 380 (7.4). The Gauteng province's science achievement score was significantly lower than the Western Cape and significantly higher than the other provinces.

Table 6: Average provincial science scale score and comparison between provinces

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

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

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

19 For a full analysis of achievement and achievement trends of all nine provinces, we refer the reader to the TIMSS 2019 Grade 9 National Report (cf. Reddy et al., 2022).

3.2. SCIENCE ACHIEVEMENT GAPS

Gauteng is a diverse province with high levels of income poverty and inequality. In an ideal world, achievement gaps should only reflect differences in the abilities and efforts of learners. But in most educational systems, the achievement gaps that exist are associated with background factors. Thus, a single provincial achievement score does not tell the full story of learners' performance in Gauteng. Rather, better insights are provided through a more nuanced achievement story reported by the SES of the school (school quintile and fee status of school).

Science achievement and ability levels by socioeconomic status of the school

Gauteng schools vary in relation to the area in which they are located and their access to infrastructure and resources. To address these imbalances, the DBE has calculated a poverty index for each public school according to the income, literacy and unemployment levels in the community around the school. Public schools are categorised into five groups, called quintiles, with Quintile 1 being the most under-resourced schools in the most economically disadvantaged communities, and Quintile 5 being the better resourced schools in more affluent communities. Table 7 reports the average mathematics achievement for schools in each DBE defined quintile category as well as independent schools[20] and the comparisons between them.

The average science achievement for learners in Quintile 1, 2 and 3 schools were similar, with no significant differences observed. The average science achievement of learners in Quintile 4 schools (407 points) was significantly higher than that of learners in Quintile 1, 2 and 3 schools but significantly lower than that of Quintile 5 and independent schools. Quintile 5 and independent did not have significant differences between their scores. However, neither of these more resourced school types reached the TIMSS centrepoint of 500 points.

Table 7: Average Gauteng science scale score, by school quintile rank and comparisons

		Comparison quintile					
Quintile Rank	Average Gauteng Science Scale Score	Independent	Quintile 5	Quintile 4	Quintile 3	Quintile 2	Quintile 1
Independent	497 (9.9)			▲	▲	▲	▲
Quintile 5	478 (9.9)			▲	▲	▲	▲
Quintile 4	407 (6.8)	▽	▽		▲	▲	▲
Quintile 3	375 (6.7)	▽	▽	▽			
Quintile 2	373 (6.9)	▽	▽	▽			
Quintile 1	376 (8.7)	▽	▽	▽			

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 where there was no statistically significant difference (blank cells).

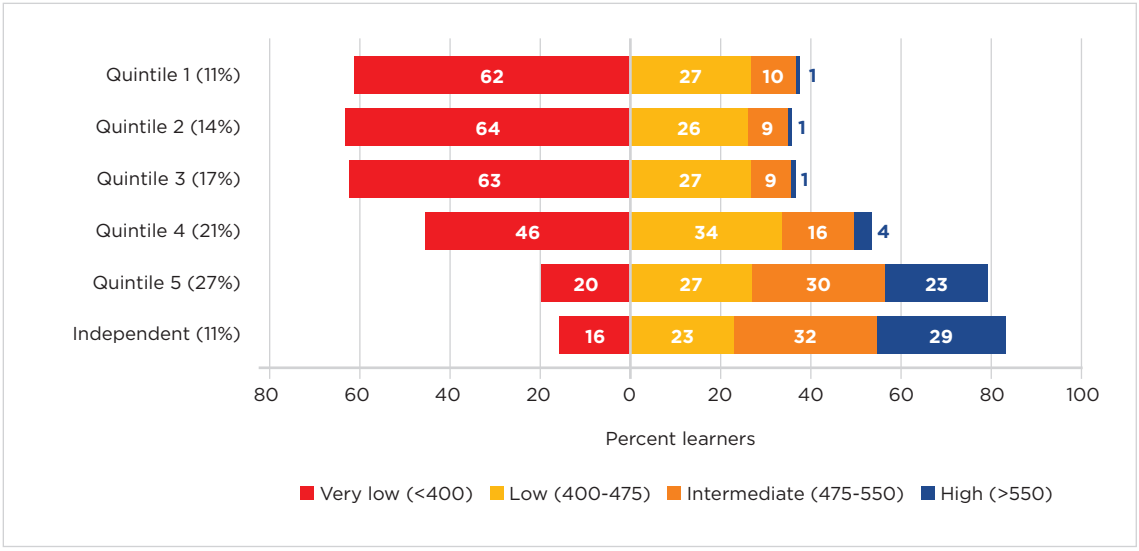
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

20 At the national level, we explicitly sample for independent schools. We did not do so in the Gauteng provincial sample. We included the average scores for independent schools as it constituted 11% of the learner sample and 16 sampled schools. These are indicative rather than representative scores.

When the achievement scale scores of each quintile are described in terms of ability levels, Figure 17 reveals a stark contrast between achievement patterns of learners in Quintile 5 and independent schools compared to learners in Quintile 4 schools and the other three quintiles.

In Quintile 1 to 3 schools, just over one third of learners achieved scores above the *Low International Benchmark* of 400 TIMSS points, i.e. demonstrating having acquired the minimum scientific knowledge and skills. The picture was better in Quintile 4 schools, where 54 percent of learners achieved scores above this benchmark. In Quintile 5 and independent schools just over 80 percent of learners had acquired basic scientific knowledge and skills. Notably, close to a quarter of learners in Quintile 5 and independent schools achieved at the *High International Benchmark* of 550 points (23 and 29 percent, respectively). These learners possess the ability to apply science knowledge and understanding in complex situations.

Figure 17: Percentage of Gauteng science learners reaching international benchmarks, by school quintile rank (% learners)



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

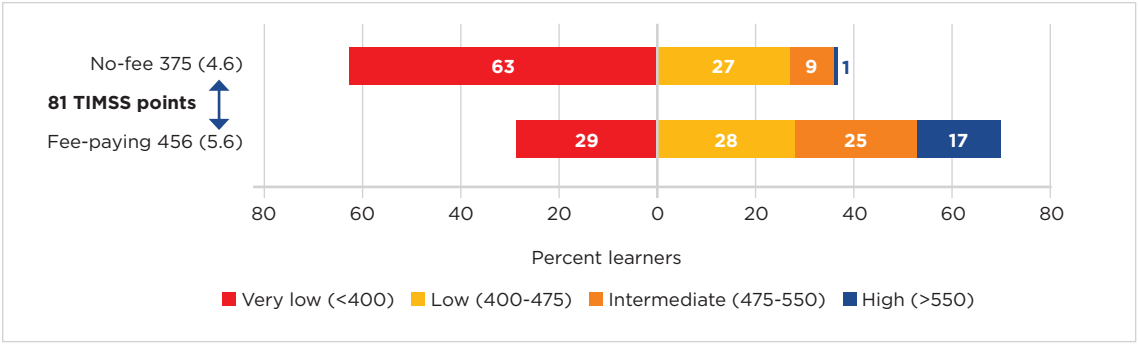
Science achievement and ability levels by school fee status

With the high levels of household poverty in the country, the amended South African Schools Act (RSA, 1996c) legislated the abolition of fees for learners attending schools in poorer communities. Government subsidises the school fees for learners in Quintile 1, 2 and 3 schools, which are called 'no-fee' schools[21]. Learners in Quintile 4 and 5 and independent schools pay fees, and their schools are designated as 'fee-paying.' Of the Gauteng learners who participated in TIMSS 2019, 41 percent attended no-fee schools and 59 percent 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. Figure 18 describes the average achievement scores and percentage of learners reaching the different international achievement benchmarks. The average science score for learners in no-fee schools was 375 (4.6) (similar to the South African average score) and in fee-paying schools it was 456 (5.6). This means an achievement gap of 81 TIMSS points in science between learners attending no-fee and fee-paying schools.

When the achievement scale scores are described in terms of ability levels, 71 percent of learners in fee-paying schools demonstrated that they had acquired basic scientific knowledge and skills. In no-fee schools, on the other hand, just over a third of learners (37%) showed they had acquired basic scientific knowledge and skills. This means that 63 percent of Gauteng Grade 9 learners in no-fee schools had not acquired the basic knowledge and skills for that grade.

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



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

The following section presents a summary of Gauteng Grade 9 learners' science achievement and the achievement gaps that were evident in TIMSS 2019.

21 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 more resourced communities, and attend schools with better qualified educators and a climate that promotes better teaching and learning.

3.3. SUMMARY: SCIENCE ACHIEVEMENT AND ACHIEVEMENT GAPS

Science performance

The Gauteng province average science achievement was in the lowest quarter of the set of TIMSS 2019 participating countries and entities. Gauteng's average science scale score of 422 (3.9) was significantly higher than the South African average score, but similar to the Abu Dhabi emirate (UAE).

Fifty-seven percent of learners had acquired basic science knowledge and skills, and 11 percent reached the higher achievement benchmarks, scoring over 550 points and thus demonstrating that they could apply scientific concepts.

The science achievement inequality (difference between the 5th and 95th percentile) was 324 TIMSS points.

Trends in Gauteng science achievement

Provincial achievements trends are cautiously interpreted because of a small sample sizes in previous TIMSS cycles. Between 2011 and 2019, science achievement improved from 396 to 422 points, a statistically significant increase of 26 points. The average improvement rate was 3.3 points each year.

During the same period, the share of learners who acquired basic science knowledge increased from 48 percent in 2011 to 57 percent in 2019.

The best gains were achieved at the lower end of the achievement distribution, which indicates that those learners with the lowest achievement are improving the most.

Gauteng science achievements in relation to other provinces

Gauteng was the second highest performing province in South Africa and achieved significantly lower science achievement scores than the Western Cape but significantly higher than all other provinces.

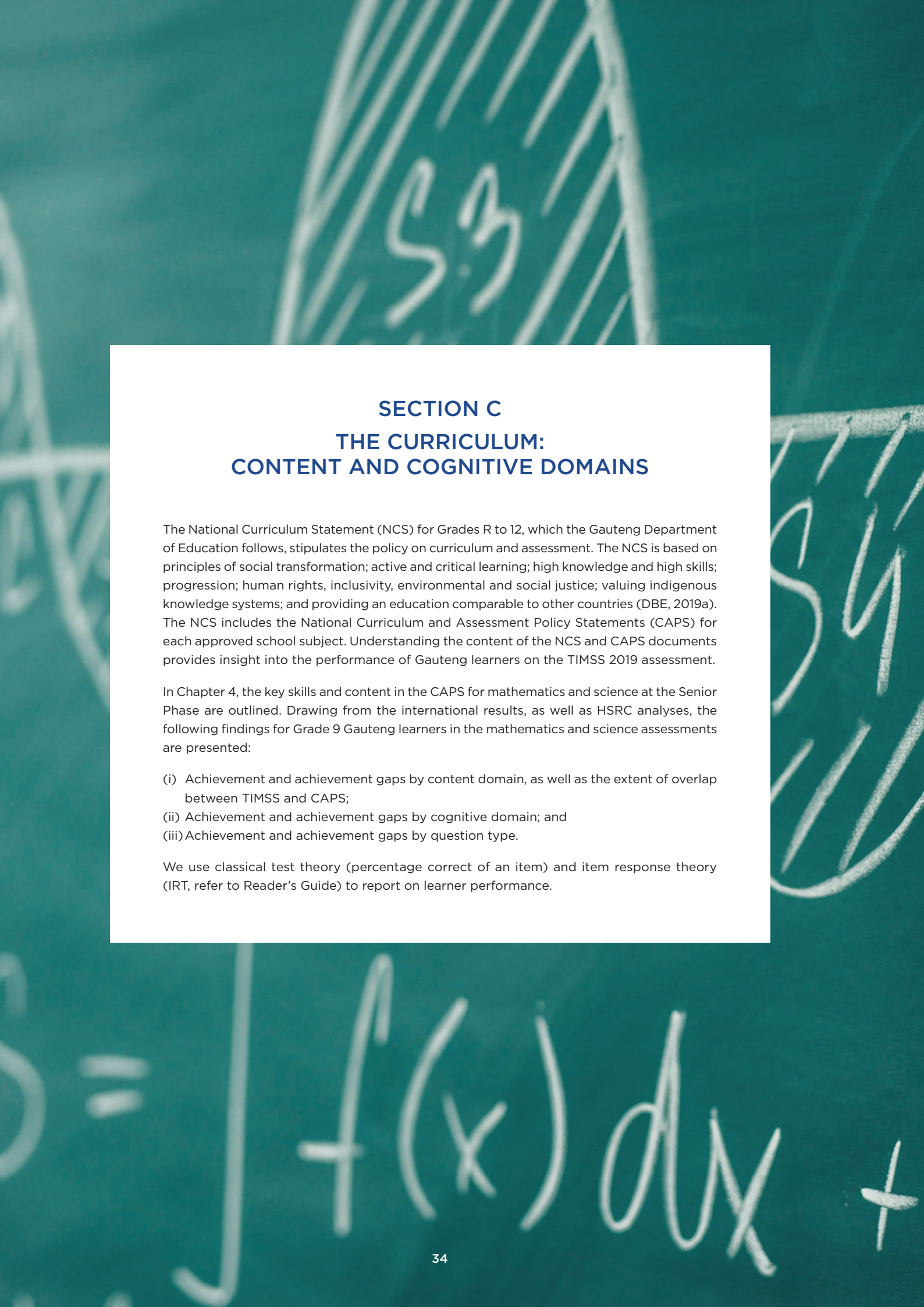
Science performance by school socioeconomic status

The average science achievement scores for learners in Quintile 1, 2 and 3 schools were not statistically different. The average science achievement of learners in Quintile 4 schools was significantly higher than that of learners in Quintile 1, 2 and 3 schools but significantly lower than that of Quintile 5 and independent schools. Although learners in Quintile 5 and independent schools significantly outperformed learners in the other four quintiles, they did not reach the TIMSS centrepoint of 500 points.

In terms of ability levels, there was a stark contrast between science achievement patterns across the different school quintiles. Just over a third of learners in Quintile 1 to 3 schools scored above the *Low International Benchmark*, compared with 54 percent in Quintile 4 schools and 80 percent from Quintile 5 and independent schools.

The average science score for learners in no-fee schools was 375 (4.6) compared to 456 (5.6) in fee-paying schools. The science achievement gap between no-fee and fee-paying schools was 81 TIMSS points.

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



SECTION C

THE CURRICULUM: CONTENT AND COGNITIVE DOMAINS

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

In Chapter 4, the key skills and content in the CAPS for mathematics and science at the Senior Phase are outlined. Drawing from the international results, as well as HSRC analyses, the following findings for Grade 9 Gauteng learners in the mathematics and science assessments are presented:

(i) Achievement and achievement gaps by content domain, as well as the extent of overlap between 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 (percentage correct of an item) and item response theory (IRT, refer to Reader's Guide) to report on learner performance.

CHAPTER FOUR

MATHEMATICS AND SCIENCE CURRICULA

To correctly respond to the mathematics and science TIMSS 2019 assessment items, learners would have needed to draw on three competencies:

- 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 TIMSS mathematics and science assessments are organised around two dimensions: content domains that describe the subject matter to be assessed, and cognitive domains that describe the thinking processes that learners use as they engage with the content. Each item in the TIMSS assessments is associated with both a content and a cognitive domain. This allows learner performance to be described in terms of both content and cognitive perspectives (Mullis & Martin, 2017). We first report our findings for mathematics, followed by science.

4.1. MATHEMATICS CURRICULUM

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

4.2. PERFORMANCE BY TIMSS MATHEMATICS CONTENT AND COGNITIVE DOMAINS

The TIMSS 2019 Senior Phase mathematics assessment (taken at Grade 8 or 9) comprised 206 items, of which each learner wrote a subset. Approximately half of these items had appeared in previous cycles, which allows for a trend measure over time. The remaining half were newly introduced for the TIMSS 2019 cycle.

Mathematics achievement by content domain

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

Table 8 reports the Gauteng Grade 9 results for the assessed mathematics content areas and the percentage match between the TIMSS curriculum and the CAPS document. This percentage match was calculated by analysing educators' responses about whether the content had been taught to the learners by the time the TIMSS assessment was taken.

Overall, the content of 79 percent of the TIMSS mathematics items were reported to have been taught before learners took the test. The degree of overlap between TIMSS and the CAPS, as reported by Gauteng mathematics educators, was highest for number (98%), followed by geometry (88%), algebra (79%) and data and probability (59%).

Performance in the algebra content domain was significantly higher than the overall Gauteng average mathematics score, while achievement in the geometry and data and probability content domains were significantly lower than the provincial score. Achievement in the number content domain was not different to the provincial score. There did not seem to be any consistent relationship between the extent of curriculum coverage and learners' achievement.

Table 8: Gauteng average mathematics achievement by content area and match between TIMSS and CAPS curriculum

	Percentage match between TIMSS and CAPS	Mathematics scale score (SE)	Difference (and significance) from overall score
All mathematics items (206 items)	79	421 (3.0)	
Number (63 items)	98	421 (3.2)	0 points
Geometry (43 items)	88	407 (3.6)	-14 points*
Algebra (61 items)	79	431 (3.7)	+10 points*
Data and Probability (39 items)	59	406 (3.5)	-15 points*

*Statistically significant difference from overall provincial mean.

Source: Mullis et al. (2020).

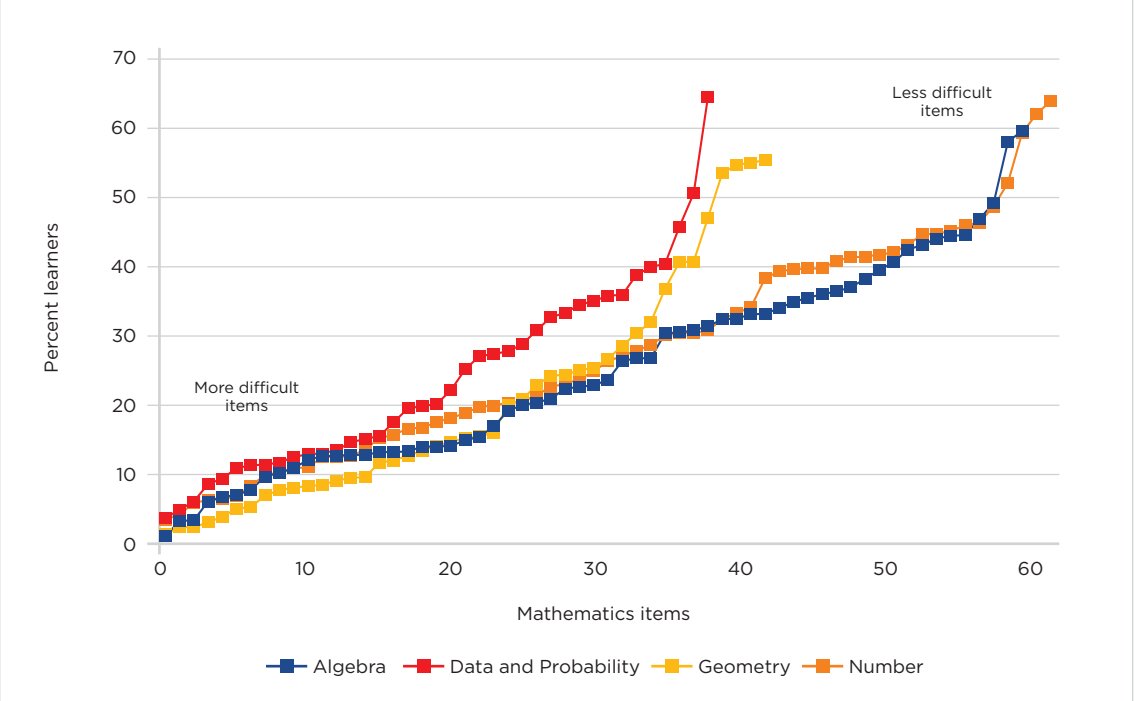
Next, we plotted a graph of the percentage of learners who gave correct responses for each item, in each of the four content areas, and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 19.

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

This is followed by the table of average percentage correct for Gauteng and the 17 countries that participated in the paper TIMSS assessment at Grade 9 for each of the domains. A higher percentage of learners provided correct responses in the number (average of 27% correct) and algebra (25%) content domains, while fewer learners answered items correctly in the data and probability (23%) and geometry (18%) domains.

The average percentage correct patterns resonate with the mathematics scale scores for each of the content domains, confirming that learners had more difficulty in the content domains of data and probability, and geometry.

Figure 19: Percentage of learners who answered items correctly per mathematics content domain



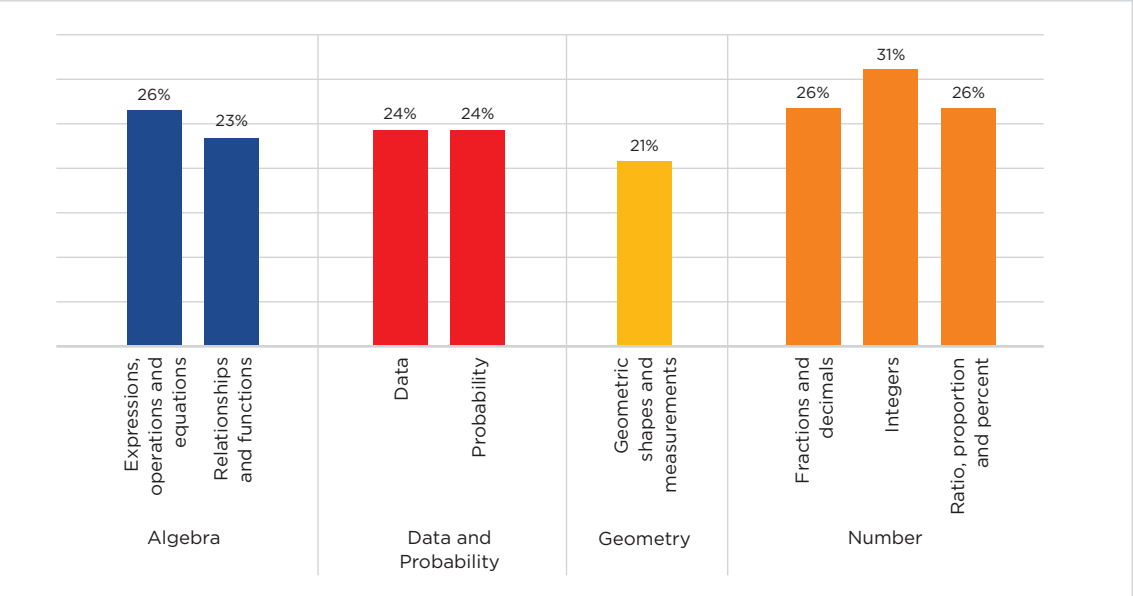
	All Items	Algebra	Data and probability	Geometry	Number
Average percent correct	24	25	23	18	27
Paper TIMSS International percent correct[22]	33	33	34	28	36

Source: Mullis et al. (2020).

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

The content domains were further disaggregated into eight mathematics topic areas. The percentage of learners who answered items correctly in each topic area is reported in Figure 20. Learners performed best in the topic areas of integers (31%) and fractions and decimals (26%). The lowest performance was in relationships and functions (23%), and geometric shapes and measurements (21%).

Figure 20: Mathematics topic areas and the average percent correct



Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Mathematics achievement by cognitive domain

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

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

Table 9 shows the percentage of items in the TIMSS assessment by each cognitive domain and the average mathematics achievement score for each domain. The average scale score for knowledge items was significantly lower than the average provincial mathematics mean score by 10 TIMSS points. No other differences were statistically significant (refer to Reader's Guide for an understanding of scale score).

Table 9: Gauteng average mathematics achievement by TIMSS cognitive domain

	Percentage items in TIMSS Curriculum	Mathematics scale score (SE)	Difference (and significance) from overall score
All mathematics items (206 items)	100	421 (3.0)	
Knowing (64 items)	35	411 (3.6)	-10 points*
Applying (96 items)	40	423 (3.3)	+2 points
Reasoning (46 items)	25	427 (3.4)	+6 points

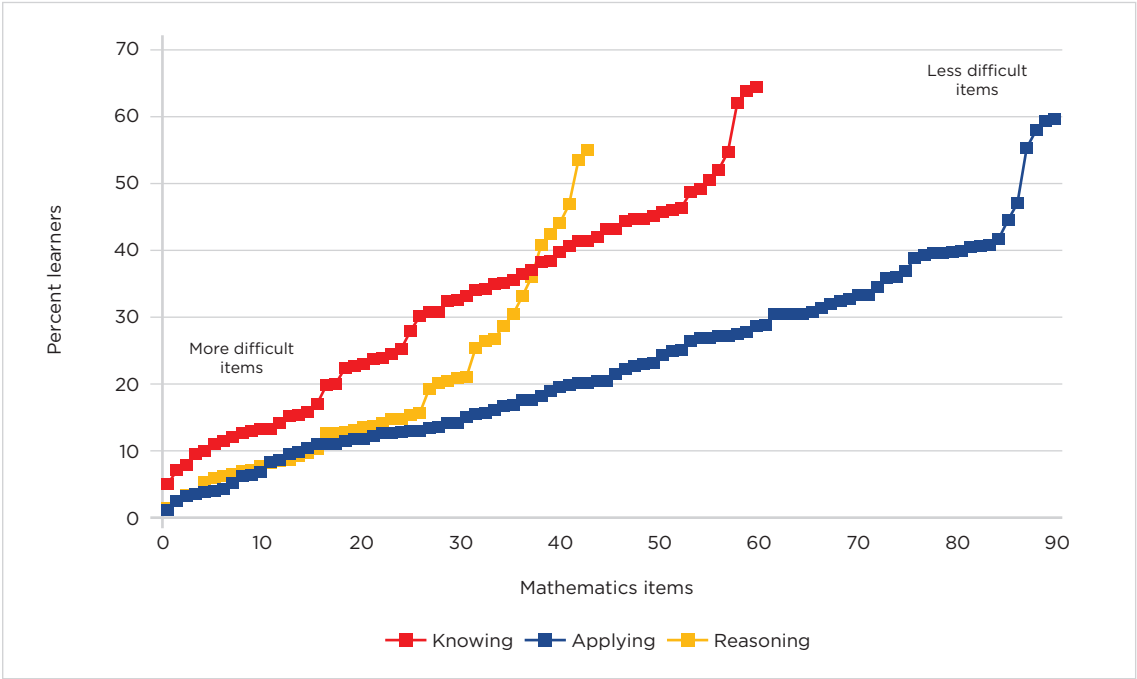
* Statistically significant difference from the overall provincial average score.

Source: Mullis et al. (2020).

We then plotted the percentage of learners who gave correct responses for each item in each of the three cognitive domains and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 21 (refer to Reader's Guide).

The average percent correct for each of the cognitive domains was highest for the knowing cognitive domain (average of 31 percent correct), followed by applying (23%) and then reasoning (17%). While more learners answered knowing items correctly, when this was combined with the difficulty level of the items, the achievement scale score for the knowing domain was lower than the overall average score.

Figure 21: Percentage of learners who answered items correctly per cognitive domain



	All Items	Knowing	Applying	Reasoning
Average percent correct	24	31	23	17
Paper TIMSS International percent correct[23]	33	41	32	25

Source: Mullis et al. (2020).

4.3. SCIENCE CURRICULUM

South African, and thus Gauteng, 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. Gauteng follows the national integrated science curriculum that is set out in the CAPS document (DBE, 2011b) (Annexure 2).

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

4.4. PERFORMANCE BY TIMSS SCIENCE CONTENT AND COGNITIVE DOMAINS

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

Science achievement by content domain

TIMSS 2019 assessed four content areas in Senior Phase science: 35 percent of the assessment items were devoted to **biology**, 20 percent to **chemistry**, 25 percent to **physics** and the remaining 20 percent to **Earth science**.

Table 10 reports the Gauteng results for the science content domains assessed and the percentage match between the TIMSS curriculum and the CAPS document. We analysed science educators' responses regarding whether the content had been taught to the learners by the time the TIMSS assessment was taken to calculate the percentage match.

Overall, the content of three-quarters of the TIMSS science items were reported to have been taught before learners took the test. The degree of overlap between TIMSS and the Gauteng curriculum was highest for biology (85%) and chemistry (82%), followed by physics (75%) and Earth science (57%). In the South African curriculum, the Earth science topics are taught in both the natural sciences and geography subject areas, possibly explaining why the overlap between the TIMSS and the CAPS curriculum is low (in TIMSS, science educators were only asked about the content taught in science).

Performance in the physics content area was significantly higher than the overall provincial score, and significantly lower for the biology content area. There was no consistent relationship between the extent of curriculum coverage and achievement.

Table 10: Gauteng average science achievement by content area and match between TIMSS and CAPS curriculum

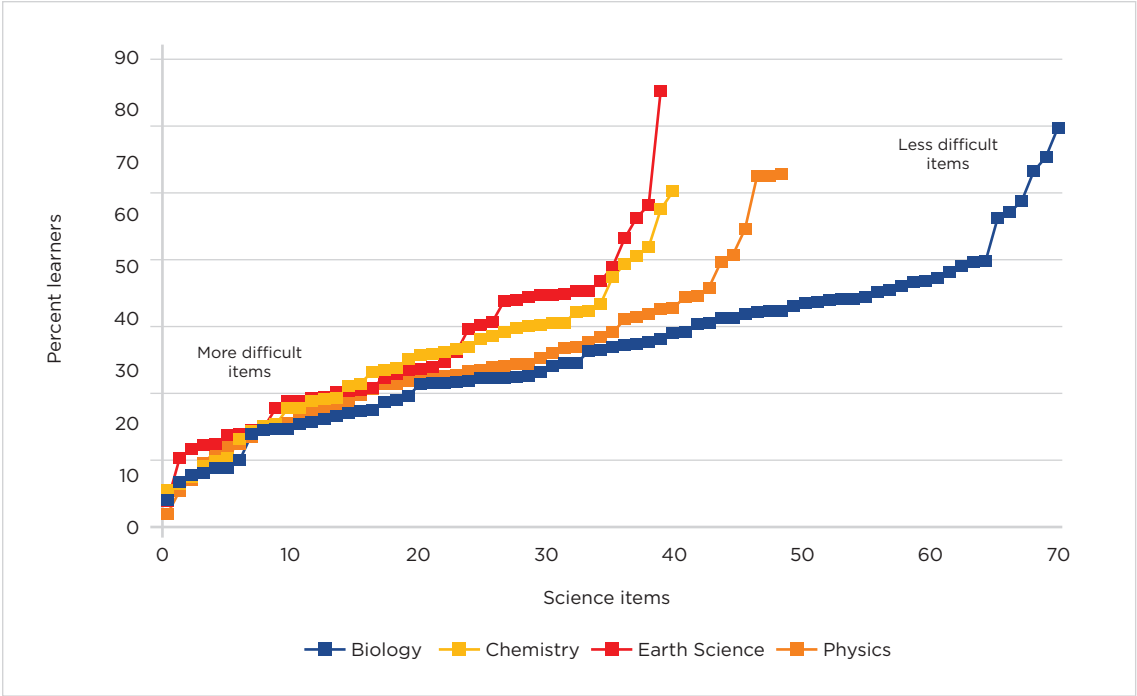
	Percentage match between TIMSS and CAPS	Science scale score (SE)	Difference (and significance) from overall score
All science items (220 items)	76	422 (3.9)	
Biology (75 items)	85	416 (3.9)	-6*
Chemistry (42 items)	82	423 (4.2)	+1
Physics (52 items)	75	428 (4.5)	+6*
Earth science (42 items)	57	419 (4.1)	-3

* Statistically significant difference from the overall provincial mean.
Source: Mullis et al. (2020).

Next, we plotted a graph of the percentage of learners who gave correct responses for each item, in each of the four content domains, and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 22 (see Reader's Guide).

The percentage of learners who answered items correctly in each of the content domains was highest for biology (average of 32 percent correct) and Earth science (32%), and slightly lower for physics (31%) and chemistry (29%).

Figure 22: Percentage of learners who answered items correctly per science content domain



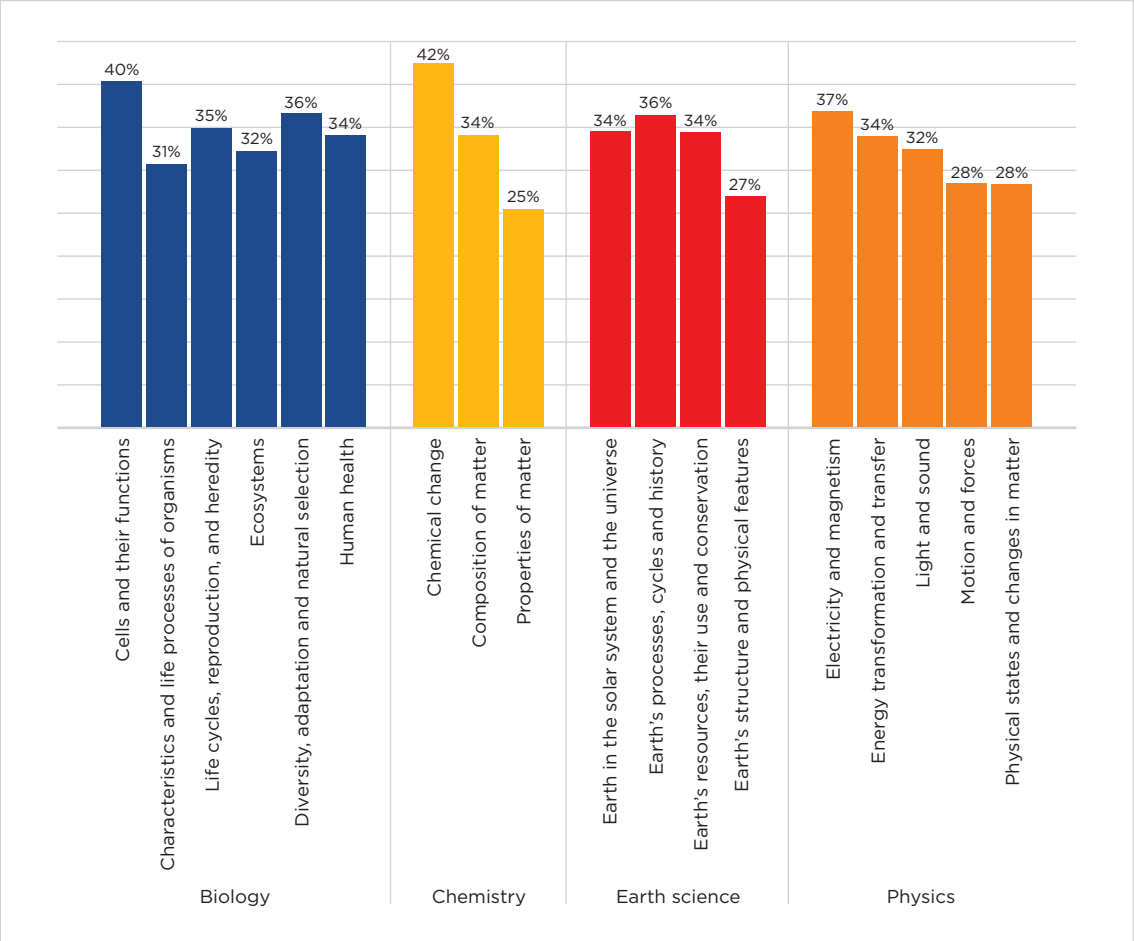
	All items	Biology	Chemistry	Earth Science	Physics
Average percent correct	31	32	29	32	31
Paper TIMSS International percent correct[24]	38	40	35	38	37

Source: Mullis et al. (2020).

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

The content domains were further disaggregated into 18 science topic areas. We calculated the average percentage of learners who answered items correctly for each of these topic areas, and this is reported in Figure 23. Learners performed best in the topic areas of chemical change (42%), cells and their functions (40%), and electricity and magnetism (37%). The lowest performance was in properties of matter (25%), motion and forces (28%), and physical states and changes in matter (28%).

Figure 23: Science topic areas and the average percent correct



Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Science achievement by cognitive domain

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

Table 11 reports the percentage of items in the TIMSS assessment by each cognitive domain and the average science achievement score for each domain. The average science scale score for knowledge and reasoning items was significantly lower than the average provincial science score, and the average science scale score for applying items was significantly higher.

Table 11: Science achievement by TIMSS cognitive domain

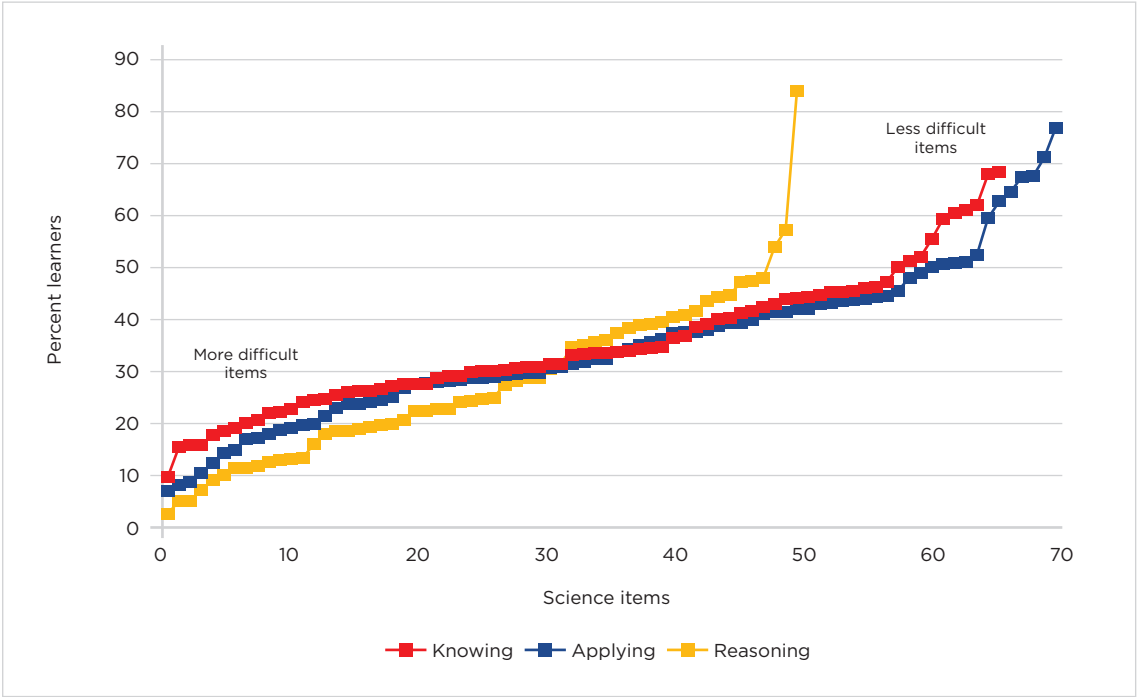
	Percentage items in TIMSS curriculum	Science scale score (SE)	Difference (and significance) from mean
All science items (220 items)	100	422 (3.9)	
Knowing (75 items)	35	413 (4.8)	-9*
Applying (80 items)	35	428 (3.7)	+6*
Reasoning (56 items)	30	417 (3.8)	-5*

*Statistically significant difference from the overall provincial mean.
Source: Mullis et al. (2020).

We plotted the percentage of learners who gave correct responses for each item in each of the three cognitive domains and arranged them from lowest to highest frequency correct. The item percent correct graph is shown in Figure 24 (see Reader's Guide).

The average percent correct was highest for knowing (average of 33 percent correct), closely followed by applying (32%) and then reasoning (26%). While more learners answered knowing items correctly, when this was combined with the difficulty level of the items, the achievement scale score for the knowing domain was lower than the average provincial science score.

Figure 24: Percentage of learners who answered correctly per cognitive domain



	All Items	Knowing	Applying	Reasoning
Average percent correct	31	33	32	26
Paper TIMSS International percent correct[25]	38	41	38	34

Source: Mullis et al. (2020).

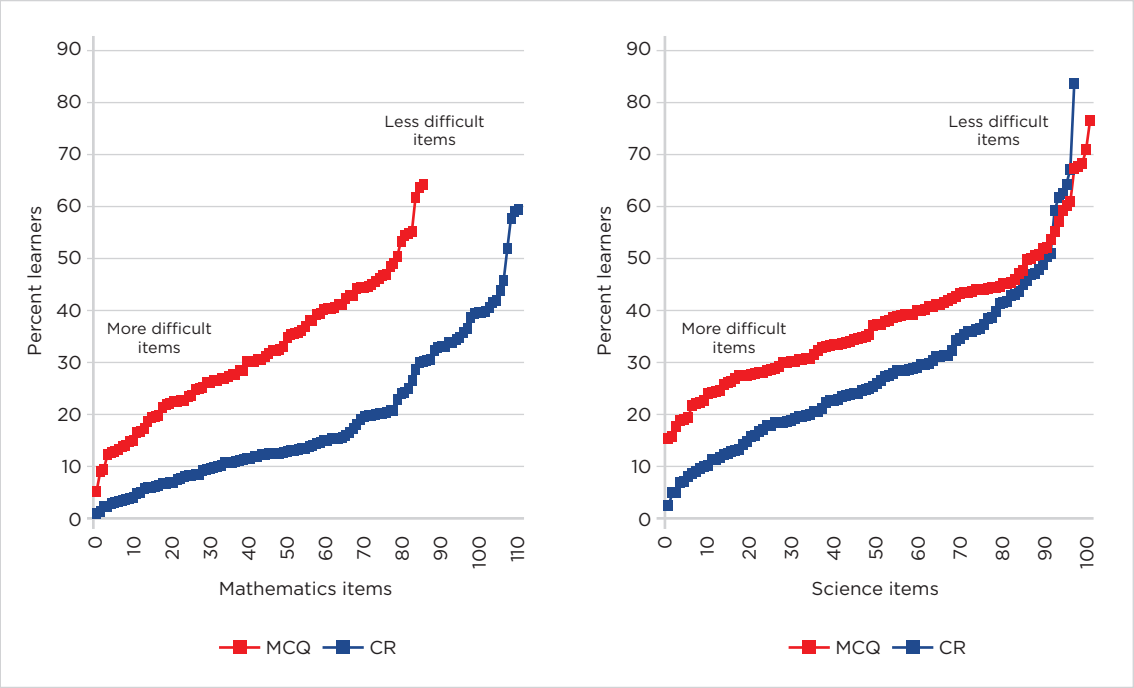
25 These figures were calculated from the 17 countries that participated in paper TIMSS.

4.5. PERFORMANCE BY QUESTION TYPE

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

We calculated the percentage of learners who responded correctly to each of the selected and constructed response items. The graphs are shown in Figure 25, along with the percentage of correct responses for mathematics and science items in both formats.

Figure 25: Percentage of Gauteng learners who answered mathematics and science selected responses (MCQs) and constructed response (CR) items correctly



	Mathematics average percent correct	Science average percent correct
Selected Response (MCQs)	32	38
Constructed Response (CR)	19	28

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Learners performed better on items requiring a selected (multiple choice) response (32 percent correct for mathematics and 38 percent for science) than on items where they had to construct a response (19 percent correct for mathematics and 28 percent for science). Analysis of learner responses to constructed items showed that learners had difficulties in writing sentences and explanations or making an argument.

In the section that follows, we provide a summary of the mathematics and science achievement gaps in TIMSS 2019 for Gauteng Grade 9 learners by content domain, cognitive domain and question type.

4.6. SUMMARY: MATHEMATICS AND SCIENCE CURRICULUM ANALYSIS

Achievement gaps by mathematics content domains

The content covered by 79 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 CAPS mathematics curriculum was highest for number (98%), followed by geometry (88%), algebra (79%), and data and probability (59%).

Performance in algebra was significantly higher than the Gauteng average mathematics score, while achievement in geometry as well as data and probability were significantly lower. There did not seem to be any consistent relationship between the extent of curriculum coverage and achievement.

Learners performed best in the integer topic area, following by fractions and decimals. The lowest performance was for the topic areas of relationships and functions, and geometric shapes and measurements.

Achievement gaps by science content domains

The content covered by three-quarters of the TIMSS science items was reported to have been taught at school before learners took the test. The degree of overlap between the TIMSS and CAPS science curriculum was highest for biology (85%) and chemistry (82%), followed by physics (75%) and Earth science (57%).

Performance in the physics content area was significantly higher than the overall score, and significantly lower for the biology content area.

Learners performed best in the topic area of chemical change, while the lowest performance was in properties of matter, motion and forces, and physical states and changes in matter.

Achievement gaps by mathematics and science cognitive demand

One-third of TIMSS items were classified as knowing, and two-thirds of the items were at the higher cognitive levels of applying and reasoning.

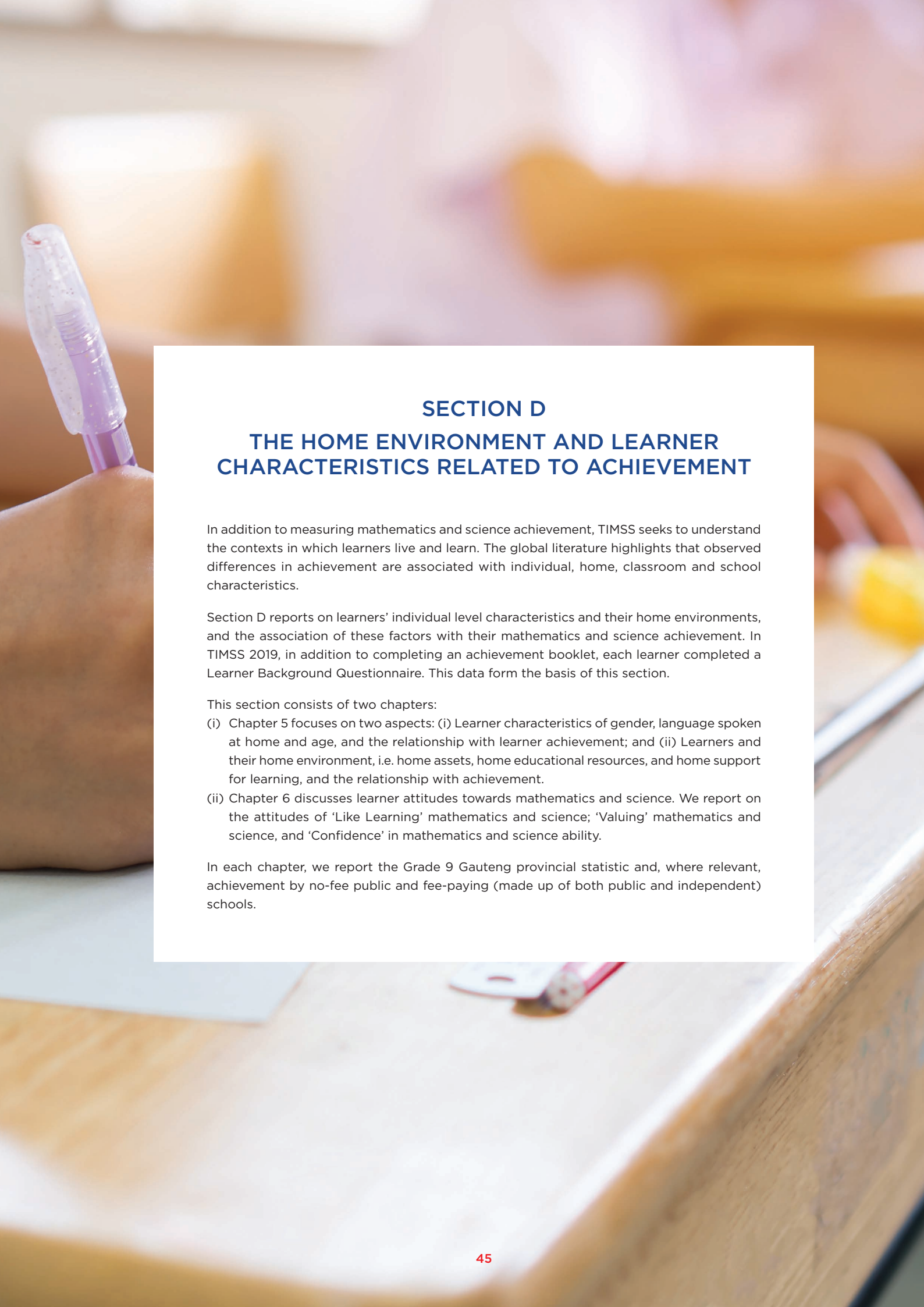
The average mathematics scale score for knowledge items was significantly lower than the average provincial score, whereas the average scores for applying and reasoning items were not statistically different.

The average science scale score for knowledge and reasoning items was significantly lower than the provincial mean score, and the average science scale score for applying items was significantly higher.

Achievement gaps by question type

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

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



SECTION D

THE HOME ENVIRONMENT AND LEARNER CHARACTERISTICS RELATED TO ACHIEVEMENT

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

Section D reports on learners' individual level characteristics and their home environments, and the association of these factors with their mathematics and science achievement. In TIMSS 2019, in addition to completing an achievement booklet, each learner completed a Learner Background Questionnaire. This data form the basis of this section.

This section consists of two chapters:

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

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

In each chapter, we report the Grade 9 Gauteng provincial statistic and, where relevant, achievement by no-fee public and fee-paying (made up of both public and independent) schools.

CHAPTER FIVE

LEARNERS AND THEIR HOME ENVIRONMENT

There are many ways in which a learner's individual characteristics and home environment are related to their 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 learners' (i) availability of home assets; (ii) access to home educational resources; and (iii) home support for learning. Each of these aspects are considered in relation to learners' achievement.

5.1. A PROFILE OF LEARNERS

Learners' gender and achievement

International evidence on the relationship between gender and achievement is mixed, not only across countries but also within countries. Gender differences in learners' educational experiences have been found to be complex and multidimensional, intersecting with race and socioeconomic status (SES). Nevertheless, national studies have found that girls tend to stay enrolled longer in school and have better educational outcomes (Zuze & Beku, 2019). In Gauteng, Letsoalo et al. (2016) found that, keeping constant socioeconomic factors such as school quintile, girls were more likely to pass the Grade 12 examinations than boys.

We examine the gender achievement patterns for Gauteng, as well as in the contexts of lower and higher economic affluence, using the fee status of the school that learners attended to differentiate between levels of affluence. In Gauteng, girls made up 55 percent of the Grade 9 sample.

Gender and mathematics achievement

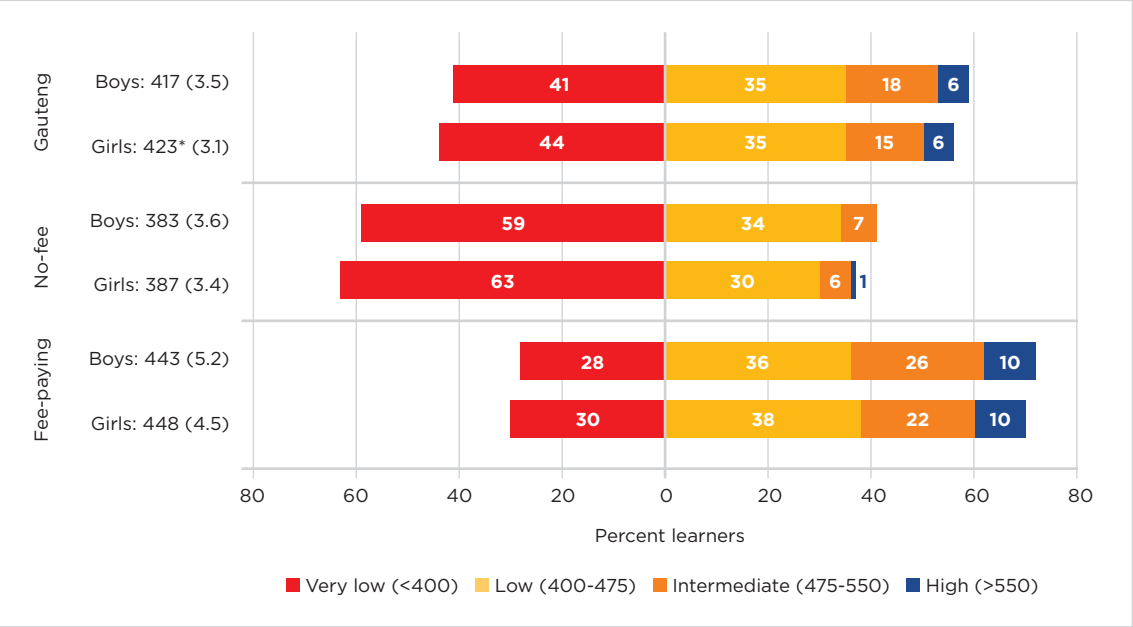
Among the 46 TIMSS countries and benchmarking participants at the Senior Phase, girls achieved significantly higher mathematics scores in eight participating entities, there was no significant gender difference in 31 entities, and boys had significantly higher achievement than girls in seven entities (Mullis et al., 2020).

The Gauteng mathematics achievement scores and international achievement benchmarks (see Reader's Guide) for girls and boys provincially, and for no-fee and fee-paying schools, are presented in Figure 26. The average achievement score for girls of 423 (3.1) was higher than for boys at 417 (3.5). This six-point difference was statistically significant.

Girls outscored boys by four TIMSS points in no-fee schools and by five points in fee-paying schools. A slightly higher proportion of girls in the province, as well as in both no-fee and fee-paying schools, had acquired basic mathematical knowledge and skills. None of these differences were statistically significant.

Our analysis also revealed a gender achievement difference by mathematics content and cognitive domains. On average girls had a significantly higher average mathematics score in the algebra content domain and in the knowing cognitive domain (Mullis et al., 2020).

Figure 26: Average mathematics scale score and percentage of learners reaching international benchmarks, by school fee status and gender



* Statistically significant achievement difference between categories.
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) dataset.

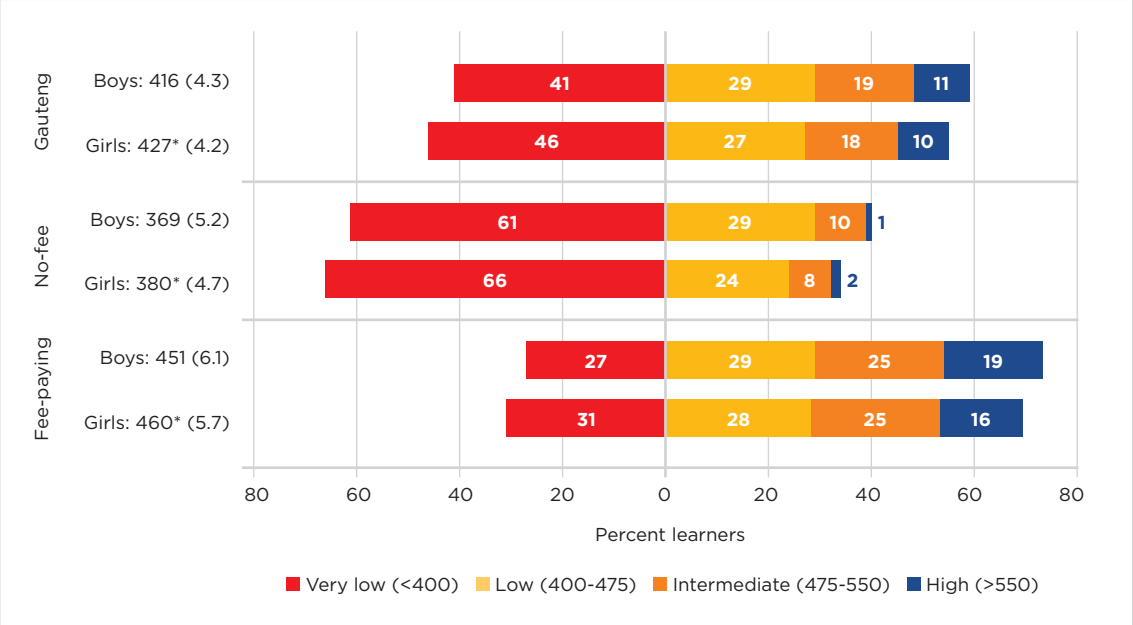
Gender and science achievement

Among the 46 TIMSS entities participating at the Senior Phase, girls achieved significantly higher science scores in 17 participating entities, there was no significant achievement difference in 22 participating entities, and boys had significantly higher achievement than girls in seven participating entities.

The Gauteng science achievement scores and international achievement benchmarks for girls and boys provincially, and in fee-paying and no-fee schools are presented in Figure 27. In the Gauteng province, the average scale score for girls of 427 (4.1) was significantly higher than for boys at 416 (3.1). Girls significantly outscored boys in no-fee schools by 11 points, and in fee-paying schools by nine points.

Our analysis revealed gender achievement differences by science content and cognitive domains. On average, girls achieved significantly higher science scores in the biology and chemistry content domains, and in the knowing and applying cognitive domain (Mullis et al., 2020).

Figure 27: Science achievement and percentage of learners reaching international benchmarks, by school fee status and gender



* Statistically significant achievement difference between categories.
Source: Authors' own calculations from TIMSS South African (Gauteng) 2019 dataset.

Learners' linguistic characteristics and achievement

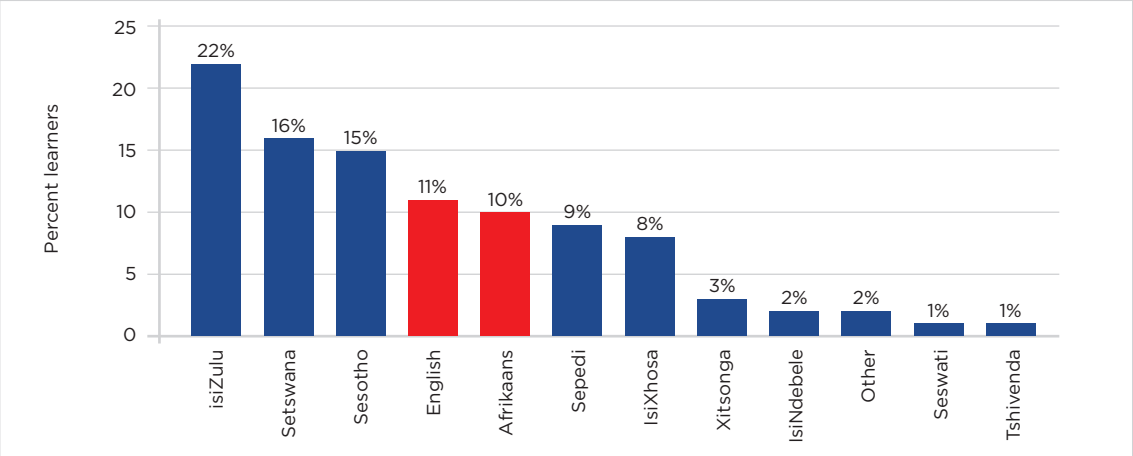
In this section we report on (i) the language that learners spoke most often at home and (ii) the extent to which they spoke the language of the test at home, and the relationship with mathematics and science achievement.

Learners' home language

Gauteng is a linguistically diverse province with representation of all 11 official languages. Figure 28 presents the languages most often spoken at home as reported by Gauteng Grade 9 learners in TIMSS 2019. isiZulu was the most common language spoken at home (22%) followed by Setswana (16%) and Sesotho (15%).

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 language spoken by 11 percent and 10 percent of learners at home, respectively. Many Gauteng Grade 9 learners may therefore not have had adequate linguistic access to the TIMSS 2019 assessment.

Figure 28: Home languages of Gauteng learners



Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Note: Afrikaans and English are highlighted as they are the languages in which TIMSS 2019 was administered.

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

Language proficiency has been shown to be related to learning and achievement (Howie, 2003; Prinsloo, Rogers & Harvey, 2018). Language proficiency in the LoLT, and assessment provides access to the learning process. Learners reported the extent to which the language of the test was spoken at home (Figure 29). This response was used here as a proxy for the ability of learners to read and understand the TIMSS assessment items.

Thirty-nine percent of Gauteng Grade 9 learners reported that they 'always or almost always' spoke the language of the test at home, 55 percent 'sometimes' spoke the test language, and six percent 'never' spoke the test language at home.

This pattern was different in no-fee and fee-paying schools. A fifth of learners in no-fee schools (22%) and half of learners (51%) in fee-paying schools frequently spoke the language of the test at home.

Figure 29 shows that learners who always or almost always spoke the language of the test at home achieved significantly higher scores than learners who sometimes or never spoke the language of the test at home. The same pattern was apparent in no-fee and fee-paying schools for both mathematics and science.

In Gauteng, the average achievement difference between learners who 'always or almost always' and 'never' spoke the language of the test at home was 64 TIMSS points (455 versus 391) for mathematics and a much higher 101 points (472 versus 371) for science.

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

Figure 29: Percentage of Gauteng learners speaking the language of the test at home, and mathematics and science achievement, by school fee status

* Statistically significant achievement difference between categories.
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) dataset.

Age of learners and achievement

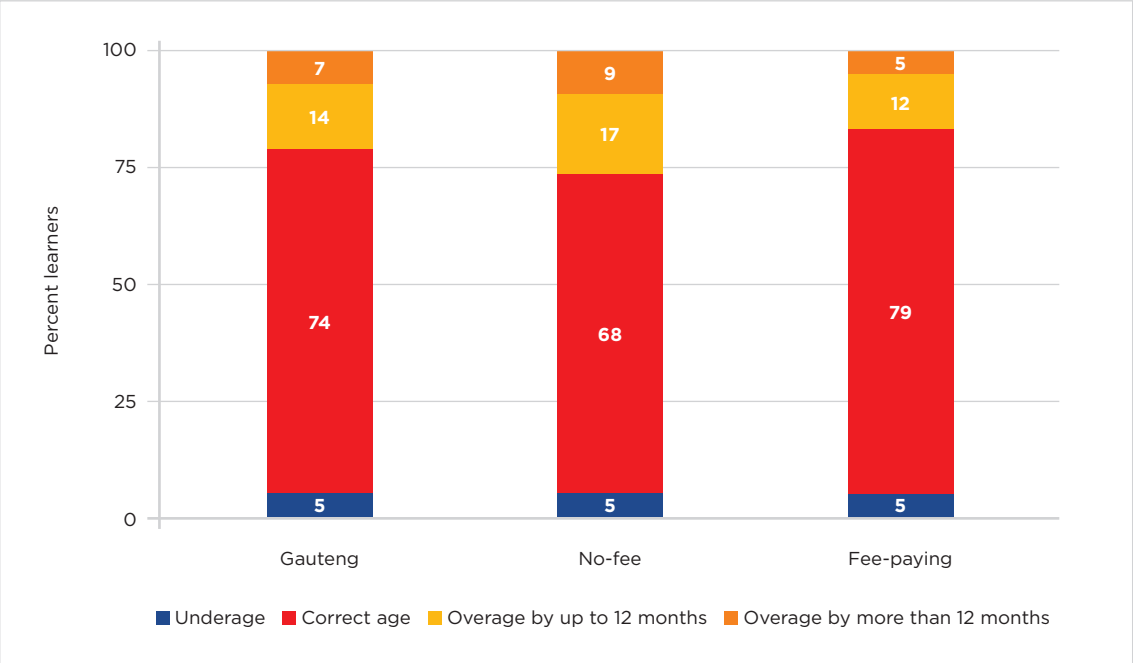
The average age of Gauteng learners in the TIMSS 2019 cohort, at the time of administration, was 15.3 years, higher than most countries participating in TIMSS[26]. Girls were younger than boys, at 15.1 years and 15.6 years, respectively.

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

We investigated the extent of overage learners in Gauteng. Grade 9 learners who started school at the correct age, and who progressed through school without repeating a grade or experiencing other interruptions, would be aged between 14.2 and 16.0 years at the time of the TIMSS administration. We then categorised other learners as either underage or overage[27]. Figure 30 reports the age distribution of learners for the Gauteng province, and for no-fee and fee-paying schools.

In Gauteng, 21 percent of Grade 9 learners were overage (compared to 30 percent nationally). This pattern was different in no-fee and fee-paying schools, where 26 percent and 17 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 30: Age distribution of TIMSS 2019 Gauteng cohort, by school fee status



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

26 The average age of Gauteng Grade 9 learners was over a year older than most countries who participated in TIMSS at Grade 8.

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

Next, we explored the relationship between learners' age and their achievement scores (Table 12). Learners who were the correct age for the grade (suggesting no grade repetition) achieved significantly higher mathematics and science scores than those who were underage or overage. The older learners achieved the lowest scores. This does suggest that previous episodes of grade repetition had done little to enhance learning and improve performance.

Table 12: Learner achievement in mathematics and science by age distribution

Age categories	Classification	Percent learners	Mathematics Mean (SE)	Science Mean (SE)
Underage	On track	5%	419* (5.2)	422* (6.1)
Correct age	On track	74%	435* (3.2)	442* (3.9)
Overage	+ 1 year or more	21%	381* (3.6)	369* (5.2)
Gauteng average			**421 (3.0)**	**422 (3.9)**

*Statistically significant difference from all other age categories.
Source: Authors' own calculations from TIMSS 2019 Gauteng Grade 9 dataset.

5.2. HOME ENVIRONMENT OF LEARNERS

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

In the context of high levels of income inequality, as in Gauteng and in South Africa, personal conditions such as where one lives and learns influence educational outcomes. TIMSS 2019 asked learners about the assets and educational resources in their homes. This allows us to explore the relationship between learners' socioeconomic environments and their achievement on the TIMSS mathematics and science assessments.

Availability of home assets

Household assets influence the extent of opportunities for a household and the differentiation across households is a signal of the inequality of opportunities. Figure 31 reports the percentage of learners who had what we categorised as basic, educational, or digital assets in their homes in 2019. These assets are used as a proxy measure of a home environment that can effectively support learning. Having these assets has been shown to be positively associated with higher mathematics and science achievement. We report on the availability of these assets, firstly at the provincial level and then for learners in no-fee and fee-paying schools.

Figure 31: Percentage of learners who had basic, educational, and digital assets at home, by school fee status

Asset type	Posession	Gauteng	No-fee	Fee-paying
Basic	Electricity*	96	93	98
	Water-flush toilet*	91	82	97
	Running tap water*	89	83	93
	Hot running water from geyser*	58	38	73
Educational	Parents have post-secondary education*	47	41	52
	Always/almost always speak test language at home*	39	20	51
	Over 25 books in the home*	24	16	29
Digital	Own cell phone*	83	78	87
	Computer or tablet*	65	51	75
	Internet connection*	52	36	63

* Statistically significant achievement difference between fee-paying and no-fee schools.
Source: Author's own calculations from TIMSS 2019 dataset.

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 successful participation in learning. According to learner reports in TIMSS 2019, almost all Gauteng Grade 9 learners had access to electricity (96%), water flush toilets (91%), and running tap water (89%). Fewer learners had access to hot running water from a geyser (58%)[28].

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) schools, making clear the inequality in the availability of resources that facilitates learning (Figure 31). These unequal home conditions predict the future educational achievement and trajectories for learners.

Learners' home educational and social capital can be gleaned by the education level of their parents, the extent to which the language of the test is spoken at home, and the number of physical 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. Forty-seven percent of learners reported that at least one of their parents/guardians had a post-secondary education[29]. Four in ten learners (39%) always or almost always spoke the language of the test at home and thus had better linguistic access to the assessment, and a quarter (24%) of learners reported having more than 25 books in their home.

While the availability of educational assets was low for most learners, the absence of these assets was significantly higher for learners in no-fee schools which can negatively affect learning outcomes.

28 In Gauteng, 77 percent of households had access to electricity, 98 percent to water from a tap and 90 percent to flush toilets (StatsSA, 2020b).

29 Twenty-one percent of learners reported that they did not know their parents' education level.

In the era of technological and digital advancement, two-thirds (65%) of learners reported that they had a computer or tablet, and just over half (52%) had an internet connection[30] at home. The availability of these assets was significantly lower for learners in no-fee schools, with 51 percent reporting having a computer or tablet and 36 percent having an internet connection at home.

Just over eight in 10 learners (83%) responded that they had their own cell phones, which could be considered a means by which schools could connect with learners.

Home asset scale

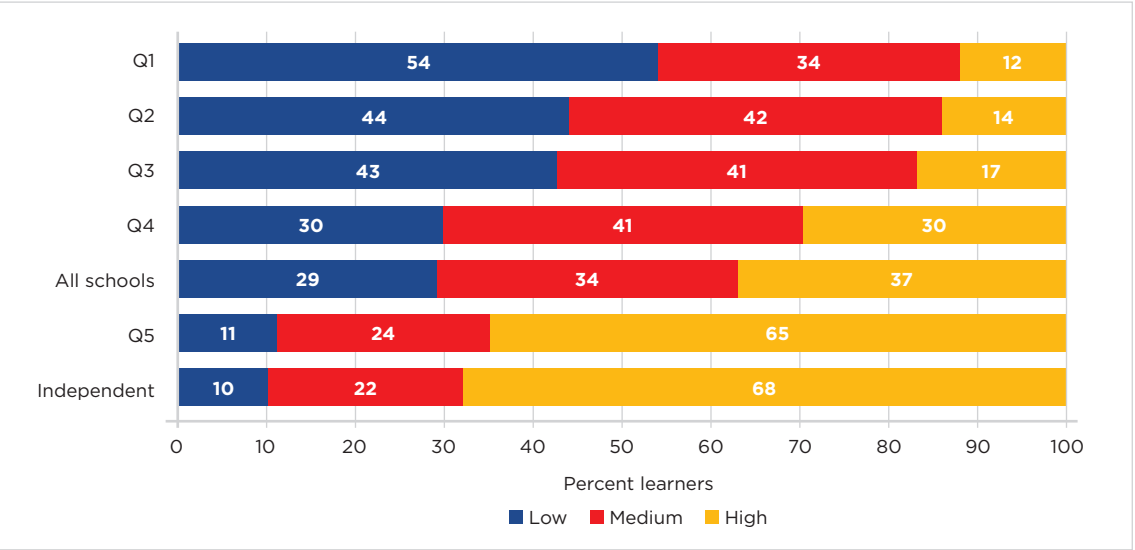
We created the *Home Asset Scale* using the national dataset and this scale was applied to the Gauteng data. The scale was based on the availability of the following assets in the home: (i) running tap water, (ii) flush toilet, (iii) hot running water, (iv) more than 25 books, and (v) an internet connection. 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* (fewer than three assets). This *Home Asset Scale* is used as a proxy of the SES of the learner.

According to this *Home Asset Scale*, 37 percent of Gauteng households were categorised as high SES, 34 percent as medium SES, and 29 percent as low SES. These proportions are in line with provincial estimates of poverty, where 34 percent of children in Gauteng are defined as multidimensionally poor (StatsSA, 2021b).

Profile of schools by learners' socioeconomic status

For a picture of the distribution of learners by SES across schools, we plotted the graph shown in Figure 32. On average just over 45 percent of learners in Quintile 1, 2 and 3 schools came from low SES homes. Learners in Quintile 4 schools were closely split across the three SES categories, with 30 percent of learners from low SES homes. The SES profile of learners in Quintile 5 and independent schools was different from the other four quintiles: two thirds of learners attending these schools came from high SES homes and only one in 10 learners were from low SES homes.

Figure 32: Profile of learners' socioeconomic status in different school types



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

30 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 16 percent of Gauteng households had a computer and 15 percent have access to internet at home (StatsSA, 2020b). For internet at home, learners may have included internet on cell phones. In 2019, the GHS reported that 68 percent of surveyed Gauteng households accessed the internet through mobile devices.

Relationship between socioeconomic status and achievement

We examined the relationship between the *Home Asset Scale*, and mathematics and science achievement. Figure 33 shows that, as expected, both learners' mathematics and science achievement had a positive relationship with the availability of home assets. Achievement was highest for learners from homes with the most assets for both mathematics (462) and science (481), and lowest for those learners from homes with the least assets (392 for mathematics and 381 for science).

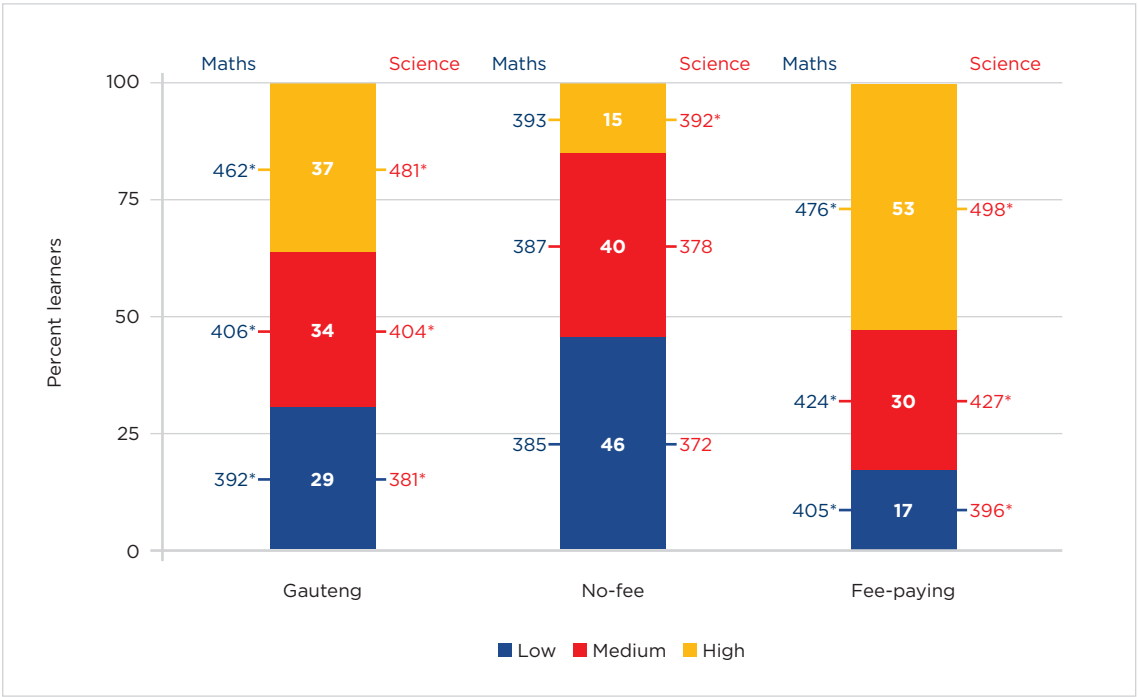
Schools were then disaggregated into the categories of no-fee and fee-paying to examine the relationship between the *Home Asset Scale*, and achievement. In no-fee schools, 15 percent of learners were categorised as coming from high SES homes, 40 percent from medium SES homes, and 46 percent from low SES homes. The corresponding figures in fee-paying schools were 53 percent, 30 percent and 17 percent, respectively.

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.

The pattern was different in no-fee schools. For mathematics we did not observe any relationship between SES and achievement, whereas science learners from high SES households achieved significantly higher scores than learners from medium and low SES households. This could be because there were compounding disadvantages at both the home and school, leading to similar achievement for learners.

Notwithstanding the results from no-fee schools, these results confirm one of the most enduring findings in the social science literature: that the circumstance you were born into is the biggest predictor of where you end up.

Figure 33: Mathematics and science achievement by socioeconomic status of the home, by school fee status



* Statistically significant achievement difference between categories.

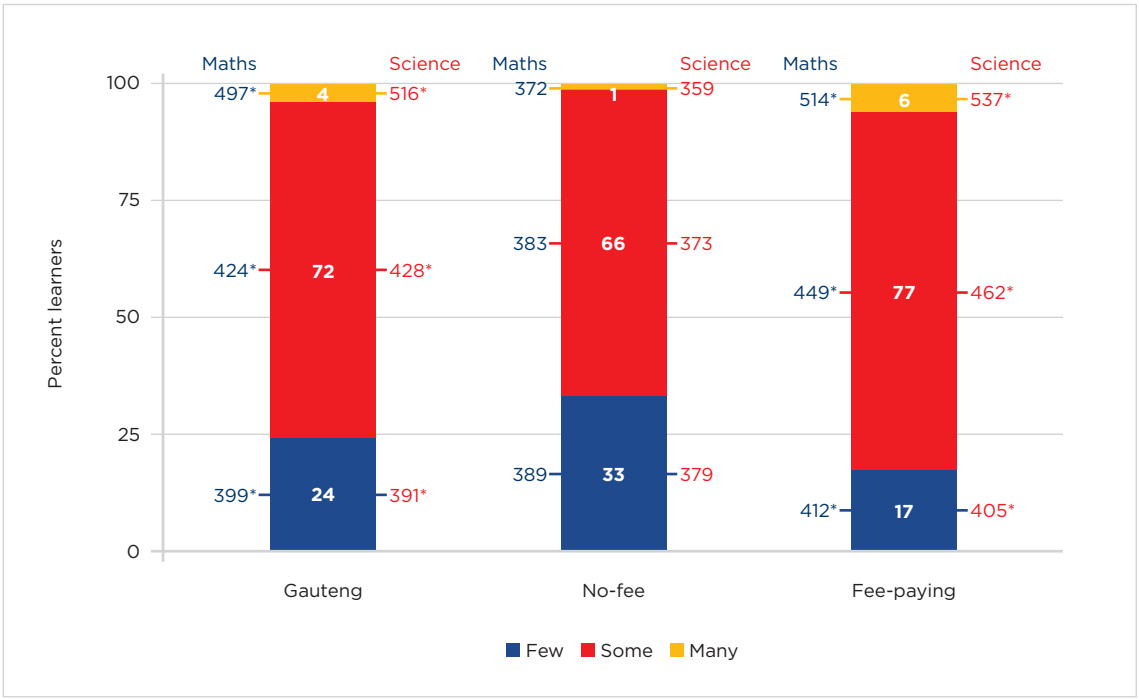
Source: Authors' own calculation from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Home educational resources and mathematics and science achievement

In addition to the availability of home assets, we explored the role of home educational resources in learners' mathematics and science achievement. TIMSS constructed a *Home Educational Resources (HER) Scale* from learner reports[31]. Figure 34 reports the proportion of learners with different levels of home educational resources, and the corresponding mathematics and science achievement by school fee status.

According to this scale, only four percent of Gauteng Grade 9 learners had 'many' home educational resources (compared to 14 percent internationally and three percent nationally). Like with the *Home Assets Scale*, there was a significant positive association between the availability of home educational resources and achievement, with learners from homes with many educational resources achieving higher than those from homes with few resources (497 versus 399 for mathematics, and 516 versus 391 for science). This pattern was the same for fee-paying schools, but in no-fee schools there were no statistically significant achievement differences linked with the availability of home resources.

Figure 34: Home Educational Resources Scale and mathematics and science achievement, by school fee status



* Statistically significant achievement difference between categories.

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

31 The HER scale summarises the availability of (i) books in the home, (ii) home study supports (own room and internet connectivity), and (iii) highest level of education of either parent. See TIMSS 2019 International Results in Mathematics and Science Report for a description of the HER Scale (https://timss2019.org/reports/download-center/; Page 290).

Home support for learning

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

TIMSS assessed parental support for homework by asking learners if their parents checked that they set aside time for, and completed, their homework. Most learners reported that their parents checked at least once a week that they had set aside time for their schoolwork (84%) and that their homework was completed (73%).

Barriers to providing support for learning

The ability of parents to help with homework can, however, be limited by their education levels, not speaking the language of the test, and the complex nature of the subject matter. Learners were asked to indicate the extent to which their parents struggled with (i) the language in which their homework was provided and (ii) the difficulty level of the homework content.

Just under half of the learners (48%) reported that their parents hardly ever struggled with the language of the homework, and slightly less (42%) hardly ever struggled with the content of the homework (Table 13 and Table 14). Learners who reported their parents hardly ever struggled with the homework language or the complexity of the subject matter achieved significantly higher mathematics and science scores than learners whose parents frequently or sometimes struggled. These findings reinforce the literature on the relationship between having more home educational capital and higher achievement scores.

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

	Hardly Ever		Sometimes		Frequently	
	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)	Percent learners	Mathematics achievement (SE)
Parents struggle with language of homework	48	448* (3.6)	34	404* (3.0)	17	384* (3.4)
Parents struggle with content of homework	42	435* (3.4)	45	420* (3.0)	13	387* (4.2)

* Statistically significant achievement difference between categories.
Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

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

	Hardly Ever		Sometimes		Frequently	
	Percent learners	Science achievement (SE)	Percent learners	Science achievement (SE)	Percent learners	Science achievement (SE)
Parents struggle with language of homework	48	460* (4.3)	34	399* (4.0)	17	370* (5.0)
Parents struggle with content of homework	42	442* (4.0)	45	421* (4.1)	13	376* (6.2)

* Statistically significant achievement difference between categories.
Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

The following section presents a summary of individual learners' characteristics and aspects of their home environments, and how these were associated with their mathematics and science achievement.

5.3. SUMMARY: LEARNER CHARACTERISTICS AND THEIR HOME ENVIRONMENT

Learners' gender and mathematics and science achievement

In Gauteng, girls made up 55 percent of the Grade 9 sample. In the bivariate analysis, girls achieved significantly higher mathematics and science scores than boys. This pattern was also observed in no-fee and fee-paying schools for science.

Learners' language proficiency and achievement

There is a high level of linguistic diversity in Gauteng schools. Learners lived in households that spoke any one of the 11 official languages. isiZulu was the most common language spoken at home (22%), followed by Setswana (16%), Sesotho (15%), English (11%) and Afrikaans (10%).

Four in ten Gauteng Grade 9 learners reported that they frequently spoke the language of the test at home: with 22 percent of learners in no-fee schools and half the learners in fee-paying schools frequently speaking the test language at home.

Learners who frequently spoke the language of the test at home achieved significantly higher mathematics and science scores than those who hardly spoke the language of the test at home. This pattern held true in no-fee and fee-paying schools as well. This analysis confirms previous studies that found that learners who frequently spoke the language of instruction, were regularly exposed to it, and used the language outside of the school, were at an advantage.

Age of learners and achievement

The average age of Gauteng Grade 9 learners was 15.3 years at the time of the TIMSS 2019 administration – with girls, on average, being younger than boys (15.1 years versus 15.6 years). Overall, 20 percent of Gauteng learners were overage in 2019 (27 percent in no-fee schools and 17 percent in fee-paying schools).

Learners who were the correct age for the grade achieved significantly higher mathematics and science scores than those who were overage. This suggests that previous episodes of grade repetition had done little to enhance learning and improve performance.

Home assets, home asset scale and achievement

Learners start from unequal home conditions, leading to inequalities in educational opportunities and outcomes. Thirty-seven percent of Gauteng Grade 9 learners came from households categorised as high SES, 34 percent as medium SES, and 29 percent as low SES.

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

Home support for learning mathematics and science

Parents helping learners with their homework is beneficial for learning, but the ability of parents to help with homework is dependent on their education levels. Just under half the learners reported that their parents were able to assist them with homework because they could understand the language and content of the homework.

Learners who reported that their parents hardly 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 struggled. These findings reinforce the literature on the relationship between having more home educational capital and higher achievement scores.

The next chapter discusses learners' attitudes to mathematics and science and the relationship with achievement.

CHAPTER SIX

LEARNER ATTITUDES TOWARDS MATHEMATICS AND SCIENCE

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

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

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

6.1. 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. Intrinsic motivation refers to undertaking an action or task for its inherent satisfaction rather than due to an external pressure or reward (Ryan & Deci, 2000). Learners who are intrinsically motivated to learn mathematics or science find the subject to be interesting and enjoyable. Previous international TIMSS findings have shown a strong relationship between the liking scales and learner achievement. Table 15 reports the learners' agreement (agreeing a lot) with statements related to their liking learning mathematics and science.

Overall, Gauteng learners expressed positive attitudes towards learning mathematics, and slightly more learners were positive towards learning science. Over 80 percent of learners reported they were happy to study mathematics and science and did not find these subjects boring.

Table 15: Percentage of learners who agreed 'a lot' with statements about liking learning mathematics and science

Learning mathematics	Percent learners 'agree a lot'	Learning science	Percent learners 'agree a lot'
I learn many interesting things in mathematics	51	I learn many interesting things in science	66
I enjoy learning mathematics	47	I enjoy learning science	54
I like mathematics	43	I like science	52
I look forward to mathematics lessons	39	I look forward to learning science in school	52
I like to solve mathematics problems	34	I like to conduct science experiments	51
I like any schoolwork that involves numbers	33	Science teaches me how things in the world work	67
Mathematics is one of my favourite subjects	30	Science is one of my favourite subjects	43
I wish I did not have to study mathematics	14	I wish I did not have to study science	11
Mathematics is boring	9	Science is boring	7

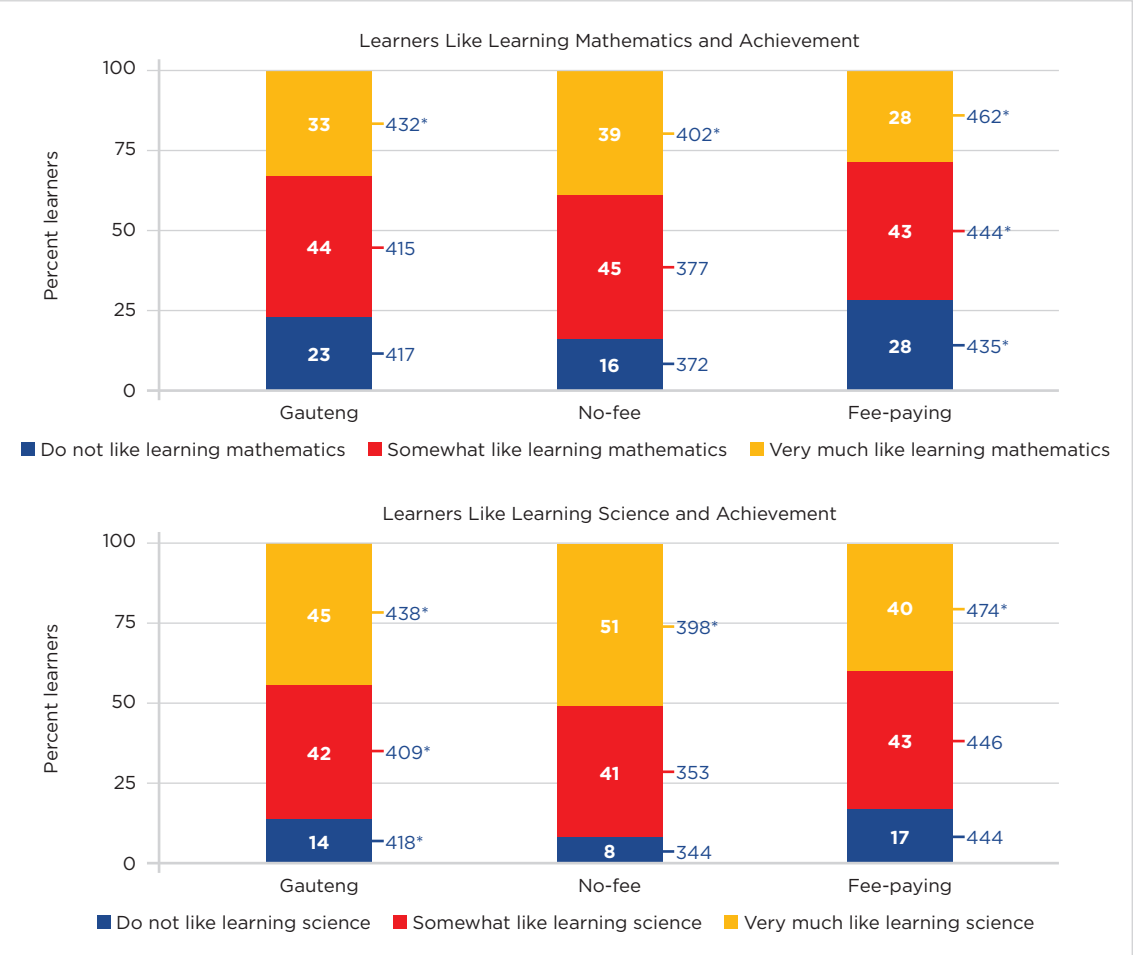
Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Learners were scored according to their responses to the nine items (Table 15) 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[32]. On this scale, 33 percent of Gauteng learners reported that they 'very much liked learning mathematics', which is higher than the international average of 20 percent, but lower than the national average of 36 percent. Forty-five percent of Gauteng learners 'very much liked learning science', again higher than the international average of 35 percent, but lower than the national average of 42 percent.

Next, we examined the association between the *Learners Like Learning Mathematics/Science* scales, and mathematics and science achievement (Figure 35) for the Gauteng province, as well as in fee-paying and no-fee schools.

At the provincial level, in no-fee schools and in fee-paying schools, learners who 'very much liked learning' mathematics (or science) achieved significantly higher mathematics (or science) scores than learners who liked mathematics (or science) less.

Figure 35: Learners like learning mathematics or science and achievement, by school fee status



* Statistically significant achievement difference between categories.

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

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

6.2. LEARNERS VALUE MATHEMATICS AND SCIENCE

TIMSS also measures extrinsic motivation through the *Learners Value Mathematics* and *Learners Value Science* scales. Extrinsic motivation refers to the drive that comes from attaining a separable outcome, such as praise, career success, money, and other incentives (Ryan & Deci, 2000). Table 16 records learners' responses of 'agreeing a lot' to statements related to their valuing mathematics or science.

In general learners saw more value to learning mathematics than science, but more learners wanted their future job in science than in mathematics.

Table 16: Percentage of learners who agreed 'a lot' with statements regarding their valuing mathematics and science

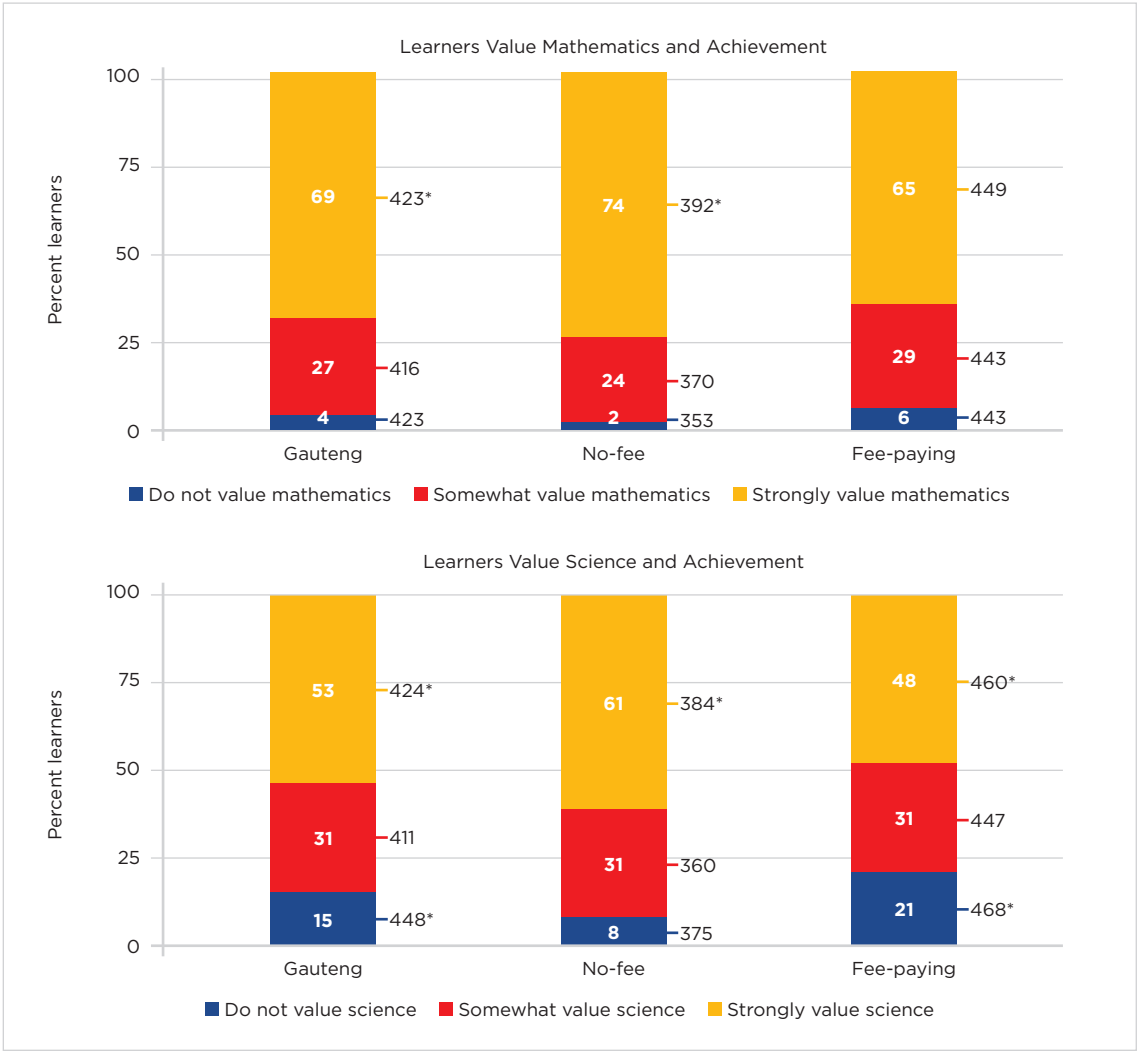
Valuing mathematics	Percent learners 'agree a lot'	Valuing science	Percent learners 'agree a lot'
I need to do well in mathematics to get into the university of my choice	82	I need to do well in science to get into the university of my choice	59
It is important to do well in mathematics	81	It is important to do well in science	64
My parents think that it is important that I do well in mathematics	77	My parents think that it is important that I do well in science	51
Learning mathematics will give me more job opportunities when I am an adult	78	Learning science will give me more job opportunities when I am an adult	59
I need to do well in mathematics to get the job I want	78	I need to do well in science to get the job I want	58
I think learning mathematics will help me in my daily life	76	I think learning science will help me in my daily life	66
It is important to learn about mathematics to get ahead in the world	67	It is important to learn about science to get ahead in the world	56
I need mathematics to learn other school subjects	53	I need science to learn other school subjects	45
I would like a job that involves using mathematics	37	I would like a job that involves using science	49

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Learners were scored according to the nine responses (Table 16) on the *Learners Value Mathematics/Science* scales. The scale was then divided into three categories: 1) *strongly value* mathematics/science, 2) *somewhat value* mathematics/science, and 3) *do not value* mathematics/science[33]. On this scale, just over two-thirds (69%) of Gauteng learners strongly valued mathematics. The corresponding international average was 37 percent, with the South African average at 68 percent. The response for science was more modest where just over half of the Gauteng learners (53%) strongly valued science. The corresponding international average was 36 percent, with the South African average at 54 percent.

Next, we examined the association between the *Learners Value Mathematics/Science* scales, and mathematics and science achievement (Figure 36). With learners reporting very high levels of valuing mathematics and science, in general there were no clear patterns of association with mathematics or science achievement.

Figure 36: Learners valuing mathematics or science and achievement, by school fee status



* Statistically significant achievement difference between categories.

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

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

6.3. LEARNERS CONFIDENT IN MATHEMATICS AND SCIENCE

Learners tend to have distinct views of their ability for success in different subjects, and their self-appraisal is often based on their past experiences and how they see themselves compared with their peers (Marsh & Craven, 2006). TIMSS measures subject-specific self-concept through the *Learners Confident* [34] *in Mathematics* and *Learners Confident in Science* scales. The results from six previous TIMSS cycles have shown a strong relationship between learners' academic self-concept and their achievement. South African analyses of the relationship between self-concept and mathematics and science achievement confirmed the strong relationship (Juan, Hannan & Namome, 2018; Juan, Reddy & Hannan, 2014).

Table 17 records the percentage of learners 'agreeing a lot' with statements related to their confidence in their mathematics or science ability. Overall, learners were more cautious and circumspect in rating their confidence in learning mathematics and science, than they were about their liking and valuing of mathematics and science.

Two in 10 mathematics learners and one in ten science learners, reported that the respective subjects (mathematics and science) were more difficult for them than for many of their classmates. A quarter of mathematics learners and 11 percent of science learners experienced high levels of anxiety about learning mathematics and science.

Table 17: Percentage of learners who agreed 'a lot' with statements regarding their confidence in mathematics and science

Confidence in mathematics	Percent learners 'agree a lot'	Confidence in science	Percent learners 'agree a lot'
Mastery experience			
Mathematics is not one of my strengths	26	Science is not one of my strengths	14
Mathematics is harder for me than any other subject	28	Science is harder for me than any other subject	11
I learn things quickly in mathematics	24	I learn things quickly in science	39
I usually do well in mathematics	22	I usually do well in science	36
I am good at working out difficult mathematics problems	15	I am good at working out difficult science problems	28
Vicarious experience			
Mathematics is more difficult for me than for many of my classmates	19	Science is more difficult for me than for many of my classmates	9
Social persuasion			
My teacher tells me I am good at mathematics	15	My teacher tells me I am good at science	21
Emotional/physiological state			
Mathematics makes me nervous	28	-	-
Mathematics makes me confused	23	Science makes me confused	11

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

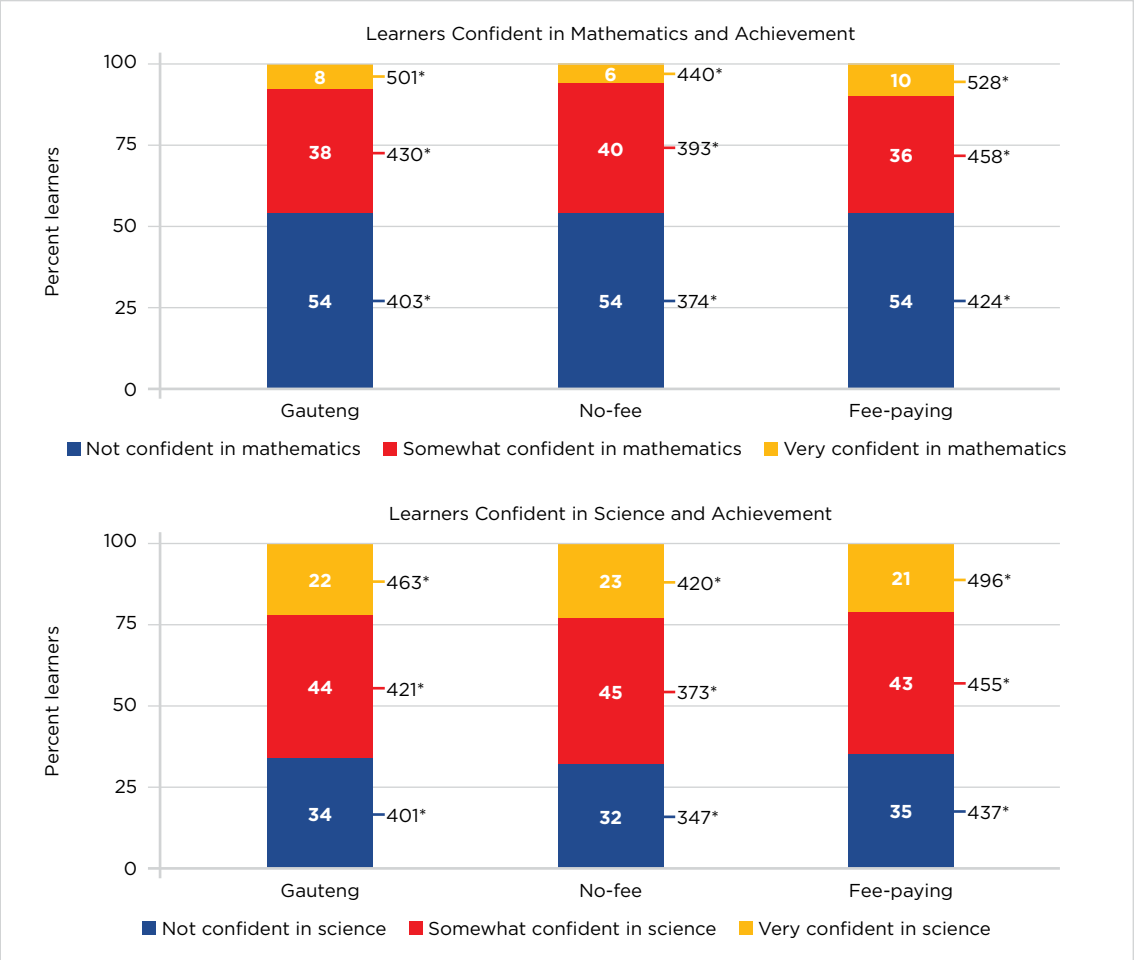
34 Some authors, such as Bandura (1977), refer to this construct as self-efficacy. Self-efficacy is a person's belief in their ability to succeed in a particular situation or cognitive strength. The elements of self-efficacy are mastery experiences, social persuasion, vicarious experiences and emotional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

Learners were scored according to the nine statements in the *Learners Confident in Mathematics* scale, and eight statements in the *Learners Confident in Science* scale (Table 17). Each scale was then divided into three categories: 1) *very confident* in mathematics/science, 2) *somewhat confident* in mathematics/science, and 3) *not confident* in mathematics/science[31]. On this scale, eight percent of Gauteng learners were categorised as 'very confident' in mathematics, compared with an international average of 15 percent and the South African average at seven percent. Twenty-two percent of learners were very confident in science, in comparison with 23 percent internationally and the South African average at 18 percent.

Next, we examined the association between the *Learners Confident in Mathematics/Science* scales, and mathematics and science achievement. For both subjects, at the provincial level, as well as in no-fee and fee-paying schools, there was a significant positive association between learners' level of confidence and their corresponding achievement (Figure 37).

This honest appraisal by learners of their mathematics and science abilities is a good starting point to encourage learners' efforts to improve their achievement scores.

Figure 37: Learners confident in mathematics or science and achievement, by school fee status



* Statistically significant achievement difference between categories.

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

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

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

6.4. SUMMARY: LEARNER ATTITUDES TOWARDS MATHEMATICS AND SCIENCE

Attitudes and achievement

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

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

Learners like learning mathematics and science

One third of mathematics learners and half of the science learners reported that they very much liked learning mathematics and science. These attitudes were more positive than most other TIMSS participating countries.

At the provincial level, as well as in no-fee and fee-paying schools, there was a significant positive association between the level of learners' liking mathematics and science, and their corresponding achievement.

Learners value mathematics and science

South African learners generally reported that they strongly valued mathematics (69%) and science (53%). The corresponding international averages were 37 percent for mathematics and 36 percent for science.

With learners reporting very high levels of valuing mathematics and science, there was no clear association between the extent of valuing these subjects, and achievement.

Learners confident in mathematics and science

Eight percent of learners reported they were very confident in mathematics, and 22 percent were very confident in science. The corresponding international averages were 15 percent and 23 percent, respectively.

At the provincial level, as well as in no-fee and fee-paying schools, there was a significant positive association between the level of learners' confidence in their mathematics and science abilities, and their corresponding achievement.

This honest appraisal by learners of their mathematics and science abilities is a good starting point to encourage learners' efforts to improve their achievement scores.

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

SECTION E

SCHOOL AND CLASSROOM FACTORS RELATED TO ACHIEVEMENT

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

TIMSS reports results by learner outcomes. The principal, mathematics and science educator responses are not representative of all principals or mathematics and science educators in Gauteng. This is because the respondents were only the principals and educators of a representative sample of learners assessed in TIMSS 2019. 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.

This section consists of two chapters:

- Chapter 7: *Schools as enabling learning environments* reports on school characteristics, principal demographics, as well as leadership and management support and school climate.
- Chapter 8: *Classrooms: Educators, Resources and Instructional Practices* reports on educators, class sizes, resources in schools and classrooms, classroom instructional practices and the use of computers for instruction.

CHAPTER SEVEN

SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

Close to a third each of the Gauteng province learners came from households characterised as either low, medium or high socioeconomic status (see Chapter 5). Lower levels of home educational capital can restrict parents' ability to support their children in their academic pursuits, and the ability to support learners substantively with subject content. According to learners, 42 percent of their parents were comfortable supporting them with their homework content. For those households that have high levels of income poverty and low educational capital, parents and society turn to schools as the institutions that have the potential to equalise opportunities and level the playing field of educational success.

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

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

(i) The school characteristics in terms of classifications by the socioeconomic status (SES) of schools, learners' SES in schools, learners' population group, and the geo-location of schools;
(ii) The school principals' demographics, as well as their leadership and management support characteristics; and
(iii) The school climate, both by describing the emphasis on academic success and promoting academic excellence; as well as the extent to which school discipline and safety problems, measured through the culture of safe and orderly schools and incidences of bullying, influenced 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 Gauteng schooling system is made up of 88 percent of learners in public schools and 12 percent in independent[36] schools (DBE, 2020c). Public schools are state controlled, while independent schools are privately governed.

The legacy of apartheid policies is still felt today as schools in Gauteng vary regarding the home background of learners, and their available infrastructure and resources. We describe the school characteristics in terms of classifications by the SES of schools, learners' SES in schools, learners' population group, and the geo-location of schools.

Profiles of schools by their socioeconomic status

The post-1994 state prioritised equitable funding to public schools to reduce disparities. Section 34(1) of the South African Schools Act 84 of 1996 states that to redress past inequalities in education provision, and to ensure the proper exercise of the rights of learners to education, the state must fund public schools from public revenue on an equitable basis (RSA, 1996c, p. 24). To this end, a school poverty index was created for each school (RSA, 2005). The National Norms and Standards for School Funding (RSA, 2012) aimed to improve equity in funding for education by ranking each school into one of five quintiles. This ranking is based on the income, unemployment rate and literacy rates of the community in which the school is located. A Quintile 1 ranking indicates an impoverished school, and a Quintile 5 ranking indicates a wealthy or affluent school (van Dyk & White, 2019).

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

The no-fee schools 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)[37]. In 2010, the no-fee policy was extended by the GDE to Quintile 4 and 5 schools who were then able to apply for no-fee status. By 2019, 393 Quintile 4 and 64 Quintile 5 schools had successfully made this application and were provided funding by the provincial government. However, this does not change their quintile categorisation (Chanee, 2020). In the analysis that follows, we continue to categorise Quintile 1, 2 and 3 schools as no-fee schools and Quintile 4 and 5 and independent schools as fee-paying schools.

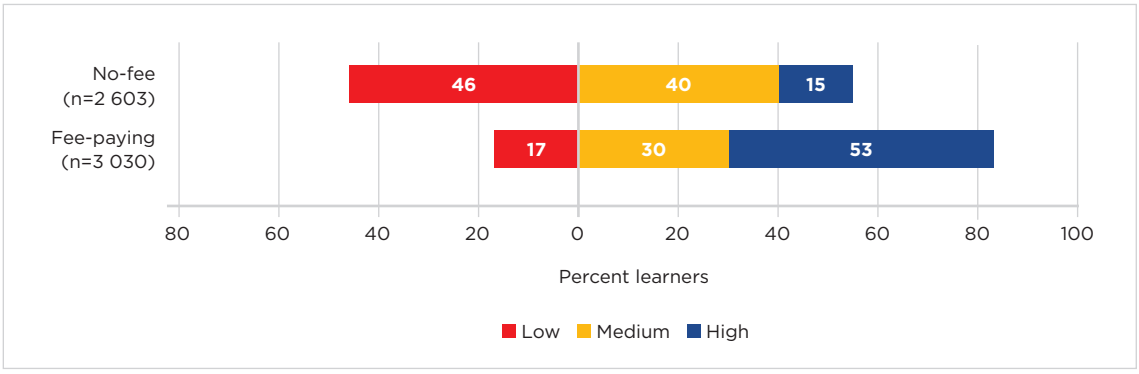
Profile of schools by socioeconomic status of learners

Since the Coleman report (Coleman et al, 1966), there has been great emphasis on how the socioeconomic composition of learners in a school is associated with individual learner achievement. Home resources refer to the tangible assets within a home, as well as the intangible assets, such as parental education levels, parental involvement in homework and home language – all of which are resources that can be drawn upon by a learner and constitutes their social capital (Visser, Juan & Feza, 2015). Gruijters and Behrman (2020) highlight three ways through which family SES is likely to influence learning in francophone African countries: (1) home educational resources, (2) health and wellbeing, and (3) disparities in school quality. They found that school quality was regarded as particularly important. These findings suggest that improving the quality of all schools is a crucial mechanism for ensuring both equity and excellence in the education system.

In Chapter 5, Figure 32 presented the SES of learners in Quintile 1 to 5 public schools. Provincially, 37 percent of Gauteng Grade 9 learners' homes were categorised as high SES, 34 percent as medium SES and 29 percent as low SES.

We aggregated schools to show the socioeconomic profile of learners in no-fee (Quintile 1, 2 and 3) and fee-paying (Quintile 4, Quintile 5 and independent) schools (Figure 40). Overall, 46 percent of learners in no-fee schools had very few basic assets at home and were categorised as coming from low SES homes. In the case of fee-paying schools, 17 percent of learners were categorised as low SES. The differences in the SES of learners gives an indication that learners enter the education system with different levels of school readiness, support and resources and learners, especially in no-fee schools, and depend on school inputs to raise their education levels. Figure 38 illustrates the continuity of conditions for learners from low SES homes to low SES schools.

Figure 38: Profile of Gauteng schools by socioeconomic status of learners



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

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

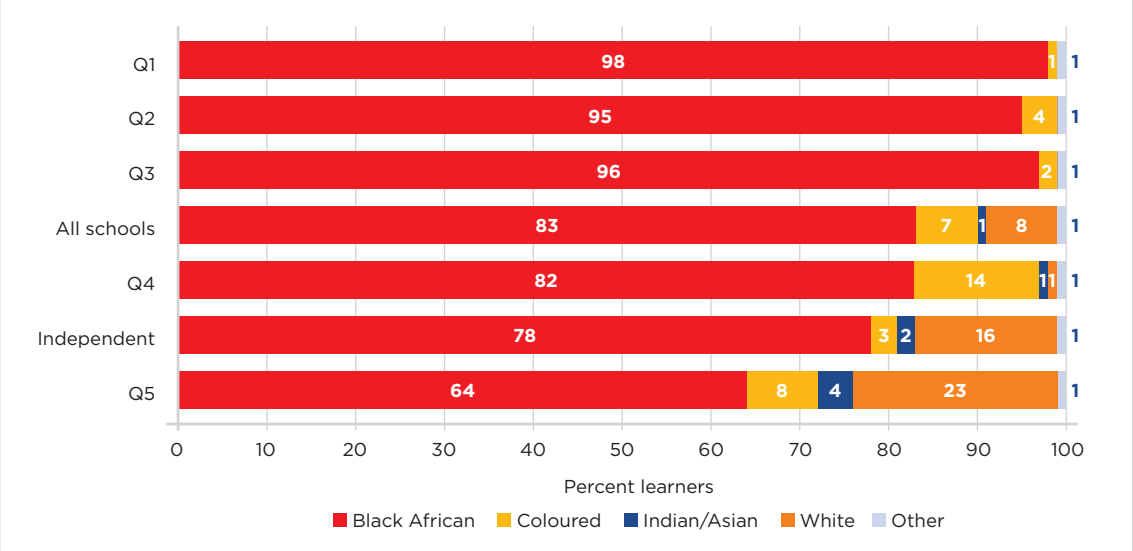
Profile of schools by population group of learners

During the apartheid period in South Africa, the Population and Registration Act (RSA, 1950) categorised all South Africans by racial classification[38] (Black African, Coloured, Indian, White), making skin colour (and other physical features) the single most important determinant in the lives of an individual. The home and school lives of learners from the different population groups were disparate, with the White group enjoying the most advantages and the Black African group being the most disadvantaged (Hunter, 2015). The legacy of apartheid continues in the lives and lived experiences of South Africans. The post-apartheid education system sought to transform the education experiences of learners by deracialising schools.

In 2019, the population of the Gauteng province was made up of 82 percent Black African, 12 percent White, three percent Coloured, and three percent Indian or Asian (StatsSA, 2020b). In the TIMSS questionnaire, learners were asked which population group they self-identified as belonging to.

Figure 39 reports the profile of schools by learners' population groups. Learners attending Quintile 1, 2 and 3 schools were almost exclusively Black African. In Quintile 4 and 5 schools, the majority were Black African learners, at 82 and 64 percent, respectively. Three-quarters of the learners in independent schools were Black African. Most White and Indian learners attended Quintile 5 and independent schools.

Figure 39: Percentage of learners by population group in different school types



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

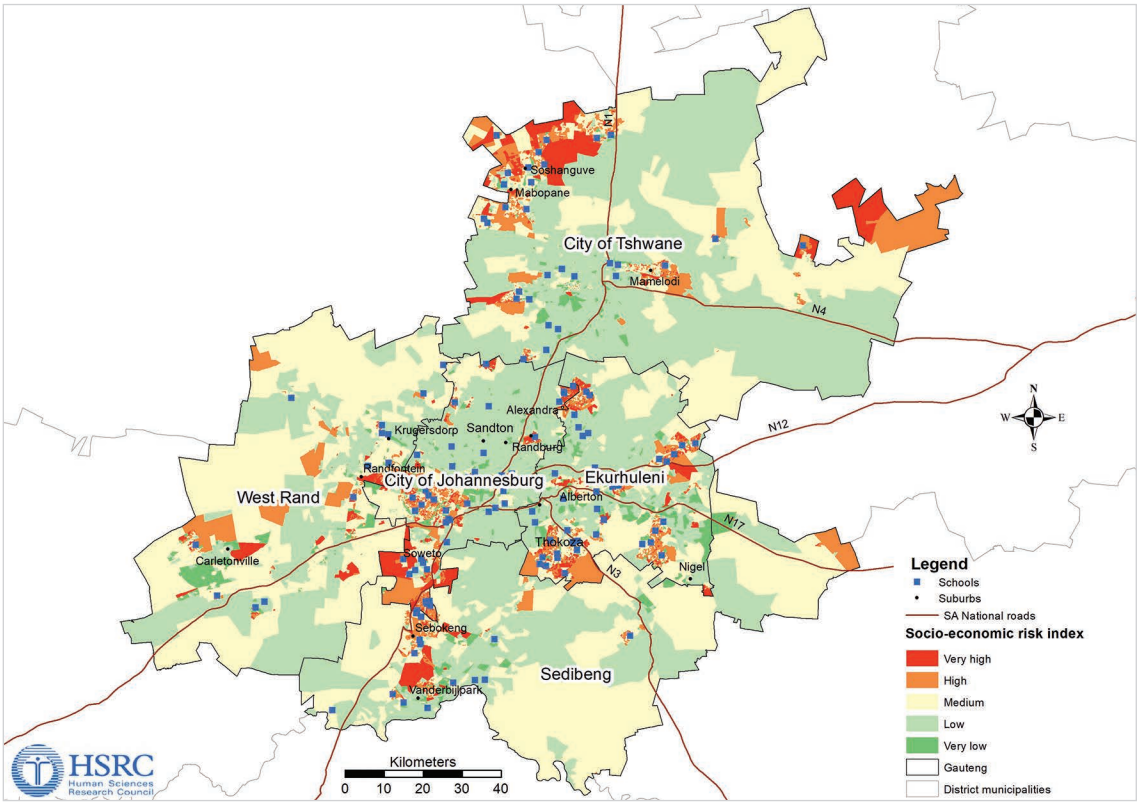
38 This report will use the term 'population groups'.

Profile of schools by their geo-location

In this section we look at the type of human settlement that surrounds the schools. The geo-location of the school serves as a proxy of both the SES of learners, as well as the culture of the community surrounding the school.

Figure 40 presents a GIS plot of the Gauteng schools that participated in TIMSS 2019. The schools are colour-coded according to the socioeconomic risk[39] of the areas surrounding the schools to provide a sense of the poverty levels. According to this map there were many schools in outer school districts located in communities categorised as having high to very high levels of socioeconomic risk.

Figure 40: GIS plot of Gauteng schools in the TIMSS sample by socioeconomic risk index



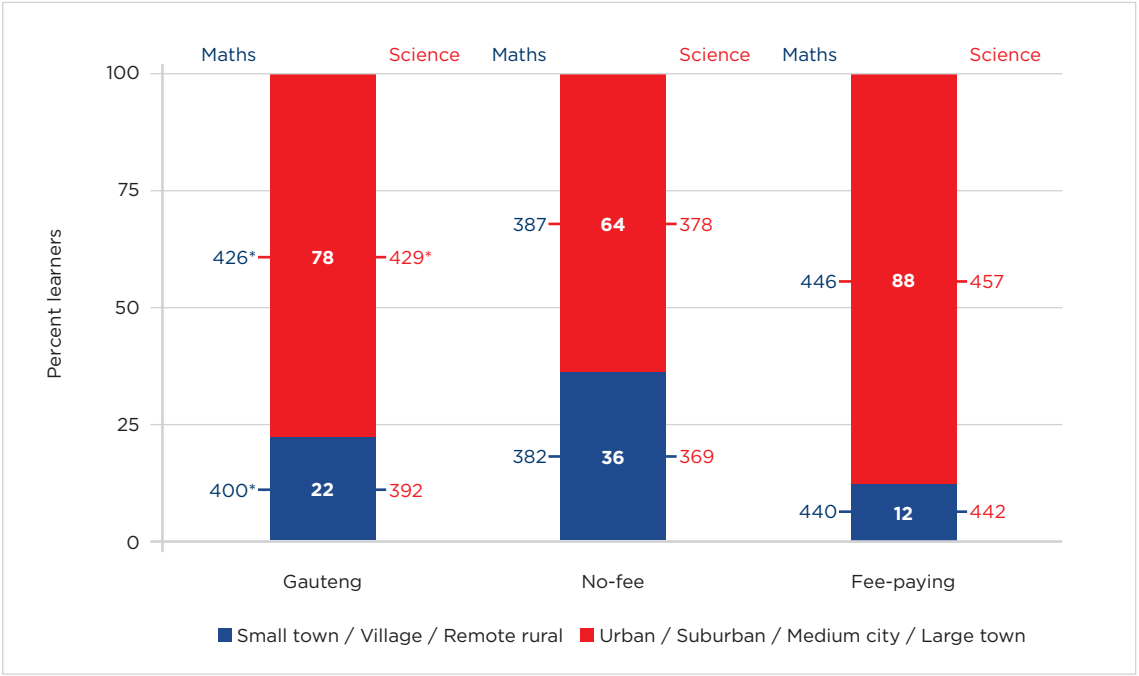
Source: Generated by Smangele Dlamini (eResearch Knowledge Centre, HSRC) using Geo Terra and EMIS data.

39 The Socioeconomic Risk Index is a composite index of six measures of SES that mark environmental, household, and individual preconditions that place people at risk of poor health.

Principals were asked to describe the area surrounding their schools to get a sense of whether the school was situated in an urban, suburban, large city, small town or village, or remote rural area. We grouped the types of areas into larger human settlements – 'urban / suburban / medium city / large town', and smaller settlements – 'small town / village / remote rural'[40]. In Gauteng, around three quarters of learners attended schools located in big and medium cities and suburbs. The profile was slightly different for no-fee and fee-paying schools, with 88 percent of learners attending fee-paying schools in big and medium cities and suburbs, compared to 64 percent of no-fee learners.

Provincially, learners attending schools in big and medium size cities and suburbs attained significantly higher mathematics and science achievement than those attending schools in small towns/villages or remote rural areas (Figure 41). This achievement difference was not significant when disaggregated by school type.

Figure 41: Learners attending schools in different geo-locations and achievement, by school fee status



* Statistically significant achievement difference between categories.

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

40 Sixteen percent of learners attended schools in small towns or villages, and six percent of learners in remote rural areas.

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 leadership and management styles, and learners' educational achievement (Osborne-Lampkin, Folsom & Herrington, 2015). In this section we report on the demographics of the principals in the TIMSS 2019 participating schools in Gauteng and describe the rating of the school principal on leadership and school management support characteristics.

School principals' educational qualifications and experience

Almost all learners (92%) attended schools where the principal's qualification was a Bachelor's degree or higher (Table 18). The principals' qualification patterns in no-fee and fee-paying schools were similar. It is, however, surprising that 10 percent of learners in fee-paying schools had a principal who had not completed a Bachelor's degree.

On average, learners attended schools where the principal had 8.4 years of experience. The experience was higher for principals in fee-paying schools (9.4 years) than in no-fee schools (6.9 years).

Table 18: Percentage of learners by principals' education level and school fee status

Principal education level	Gauteng	No-fee	Fee-paying
Completed post-graduate degree	18	16	20
Completed Bachelor's degree	74	81	70
Did not complete Bachelor's degree	8	4	10

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

Principals' leadership style 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 (2018), 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 their principal's leadership on seven statements and school management support on five statements. In Table 19 and Table 20 we report the Gauteng mathematics educators' responses, by percentage of learners who attended schools where principals' leadership and management support were rated highly as well as characteristics that were statistically significantly different between fee-paying and no-fee schools.

Table 19: Percentage of learners attending schools where educators highly rated principals' leadership

The principal...	Percent learners in schools rated 'agree a lot'		
	Gauteng	No-fee	Fee-paying
lets the teaching staff know what is expected of them	76	71	79
is friendly and approachable	74	68	78
is willing to make changes	62	56	67
maintains definite standards of performance	62	54	68
puts suggestions made by the teaching staff into operation	54	43*	62
explores all sides of topics and recognises that other opinions exist	53	44*	60
treats all staff as his or her equal	52	44	58

* Statistically significant achievement difference between categories.

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

Table 20: 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'		
	Gauteng	No-fee	Fee-paying
to protect teaching and learning time	74	67	79
to collaborate with educators to plan instruction	67	61	71
for educators' professional development	65	64	67
for instructional support to educators	65	61	67
by observing teaching practices through classroom visits	54	50	56

Note: There were no statistically significant differences between no-fee and fee-paying schools.
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Most learners attended schools where educators rated the principals' leadership highly. Approximately three-quarters of learners attended schools where the principal was rated highly on: letting the teaching staff know what is expected of them (76%) and being friendly and approachable (74%). Between half and two-thirds of the learners attended schools where the principal was rated highly on the other listed leadership attributes.

Educators in fee-paying schools, in comparison to no-fee schools, rated the principal higher on almost all characteristics but significantly higher for 'puts suggestions made by the teaching staff into operation' and 'explores all sides of topics and recognises that other opinions exist'.

Generally, around two-thirds of learners attended schools where most attributes of support by school management were rated highly. According to educator reports, teaching and learning time was protected (74%) and there was collaboration with educators to plan instruction (67%). The lowest rating was for the attribute 'observing teaching practices through classroom visits' (54%). There were no significant differences in the responses in fee-paying and no-fee schools.

7.3. SCHOOL CLIMATE

School climate is a multidimensional index of factors that cumulatively provide a representation of the overall school atmosphere (Winnaar, Arends & Beku, 2018). Well-performing schools have a positive school climate that (i) emphasises and promotes academic success and (ii) provides a safe and orderly space for both learners and educators. In this section we report on schools' emphasis on academic success; the promotion of academic excellence in mathematics and science; and the extent of discipline and safety problems in schools, measured through levels of safety and orderliness, and bullying.

Emphasis placed on academic success

A positive school atmosphere with high expectations for academic excellence can contribute to the success of a school. Gauteng principals and mathematics and science educators rated their schools on 11 characteristics relating to how educators, parents and learners emphasised academic success[41].

Table 21 provides principals' responses, rating a given aspect as 'high' or 'very high'. The results are reported as the percentage of learners attending schools given this rating for each statement.

Principals rated the educator, parent and learner differently on characteristics emphasising academic success. Principals rated educators' emphasis on academic success highly, reporting that around three quarters of learners were taught by educators who understood curricular goals, had high expectations for learner achievement and high success in implementing the school curriculum. Two-thirds of learners were taught by educators who had the ability to inspire them.

41 Mathematics and science educators were asked the same set of questions.

Significantly more learners in fee-paying than in no-fee schools attended schools where principals reported that educators successfully implemented the schools' curriculum.

Principals' rating of parental involvement in activities to promote academic excellence was not flattering. While they reported that half of the parents had high expectations for learner achievement (60%), they lamented the parental support (19%), involvement (18%), and commitment (16%) to school activities and learner achievement. Significantly more parents in fee-paying than in no-fee schools had high 'expectations for learner achievement' and provided 'support for learner achievement'.

According to the principals' ratings, 43 percent of learners respected academic excellence, and 32 percent had the ability to do well in school, but only 28 percent demonstrated the desire to do well in school. There were significantly more learners in fee-paying than in no-fee schools who respected academic excellence.

Table 21: Principals' responses to the characteristics of school emphasis on academic success

Characteristics of school emphasis on academic success	Percent learners in schools rated 'very high or high'		
	Gauteng	No-fee	Fee-paying
EDUCATORS'...			
understanding of curricular goals	78	69	85
expectations for learner achievement	75	74	76
degree of success in implementing the schools' curriculum	74	64*	80
ability to inspire learners	64	60	67
PARENTAL...			
expectations for learner achievement	60	54*	64
support for learner achievement	19	13*	23
involvement in school activities	18	14	21
commitment to ensure that learners are ready to learn	16	12	19
LEARNERS'...			
respect for classmates who excel academically	43	31*	51
ability to reach school's academic goals	32	25	36
desire to do well in school	28	25	31

* Statistically significant achievement difference between categories.

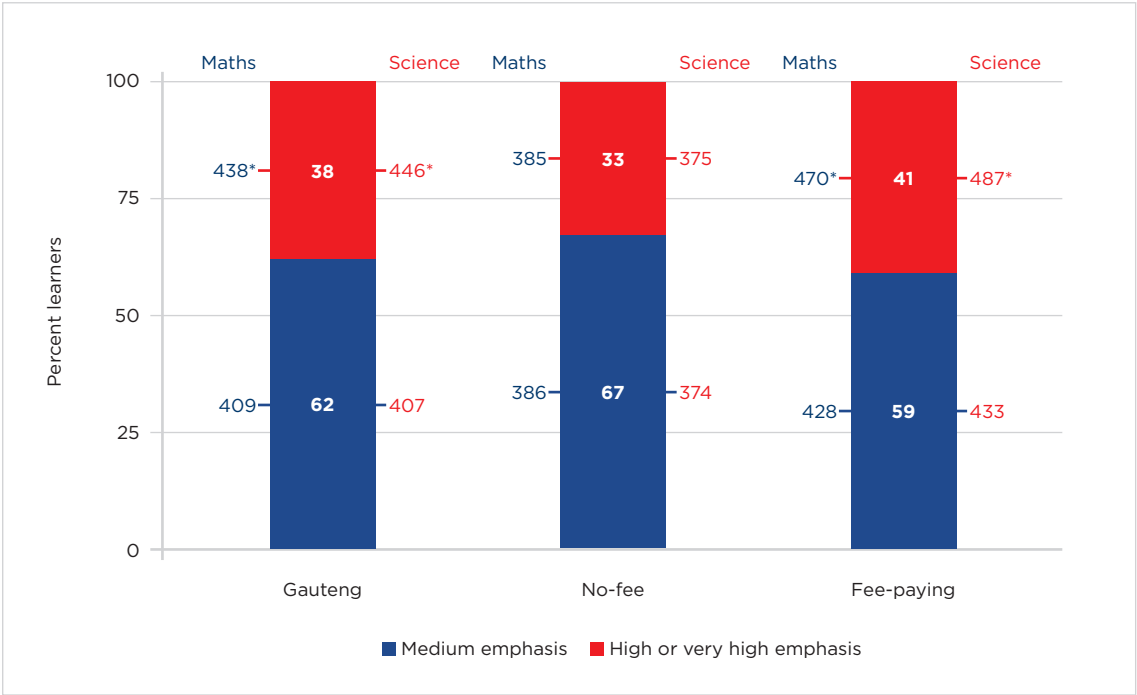
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Using the preceding set of items, TIMSS created a *School Emphasis on Academic Success Scale*[42]. The categories used were learners attending schools placing 1) a *medium emphasis* on academic success or 2) a *high or very high* emphasis on academic success. Figure 42 reports the percentage of learners attending each of the school types and the relationship with mathematics and science achievement.

In Gauteng, 38 percent of learners attended schools that placed a higher emphasis on academic success. This figure was lower than the international average of 57 percent of learners, but higher than the South African average of 31 percent. A third of learners in no-fee schools attended schools that principals reported placed a high or very high emphasis on academic success, compared to 41 percent of learners in fee paying schools.

Learners attending schools that placed a higher emphasis on academic success achieved significantly higher mathematics and science scores than learners who attended schools that placed a medium emphasis on academic success. We observed this relationship in fee-paying schools, but not in no-fee schools, probably because of over-rating the characteristics.

Figure 42: Emphasis on academic success and achievement, by school fee status



* Statistically significant achievement difference between categories.

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

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

Schools promoting academic excellence in mathematics and science

Schools can promote academic excellence through various activities. Principals responded to a set of eight items about activities in their schools that promoted academic excellence in mathematics and science (Table 22). According to the principal reports, learners could participate in several school-organised mathematics and science activities to improve their academic performance as well as interest: extra time with interested learners (68%), extra lessons to excel (63%), special activities for interested learners (41%) and promoting interest through clubs and competitions (34%).

More learners in fee-paying schools than in no-fee schools had access to activities that promoted academic excellence, except for initiatives such as learner clubs and competitions. However, the difference was only statistically significant for schools spending extra time with interested learners and providing extra lessons to help learners excel in mathematics and science (favouring fee-paying schools).

Table 22: Principals' responses to the characteristics of schools promoting academic excellence, by school fee status

Activities to promote academic excellence	Percent learners in schools rated 'agree a lot'		
	Gauteng	No-fee	Fee-paying
Mathematics and science educators in this school spend extra time working with learners interested in mathematics and science	68	58*	76
The school provides extra lessons to help learners excel in mathematics and science	63	50*	72
The school provides learners with information about career options in mathematics and science	58	52	63
The school promotes professional development for educators of mathematics and science	58	51	62
The school encourages learners to continue studying mathematics and science in the future	54	50	56
The school has a specific goal to improve mathematics and science education	54	48	58
The school provides special activities in mathematics and science for interested learners	41	34	47
The school has initiatives to promote learner interest in mathematics and science (e.g., learner clubs, competitions)	34	37	32

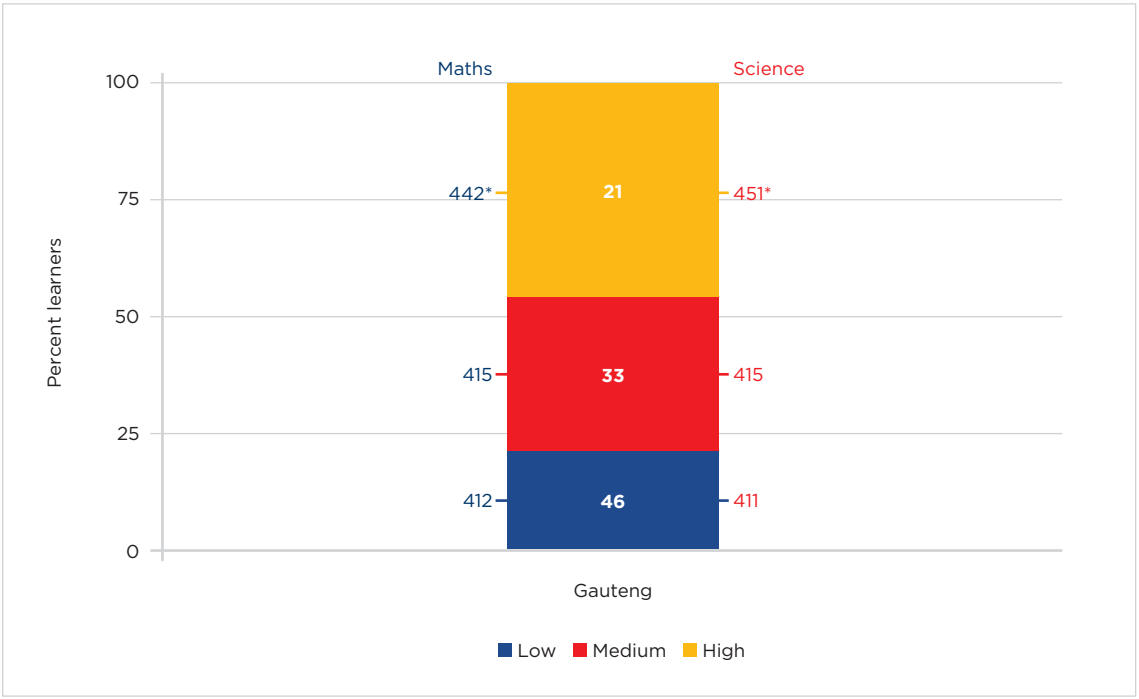
* Statistically significant achievement difference between categories.

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

Using six[43] of the eight items, the HSRC created a *School Promoting Academic Excellence Scale*. Figure 43 shows the relationship between the extent to which schools promoted excellence in mathematics and science (*low, medium or high*), and learners' achievement in these subjects.

One in five learners (21%) were in schools where there were a high number of activities promoting academic excellence, while almost half the learners (46%) were in schools with a low number of such activities. Learners who experienced a high number of school activities that promoted academic excellence in mathematics and science achieved significantly higher scores in these subjects than learners who experienced a medium or low number of activities (442 versus 412 for mathematics and 451 versus 411 for science).

Figure 43: Learners in schools promoting excellence and achievement



* Statistically significant achievement difference between categories.

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

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

Safe and orderly schools

Previous TIMSS reports have consistently shown a positive relationship between learner achievement, and educator and principal reports of school safety and orderliness. School effectiveness research analysing TIMSS and Progress in International Reading Literacy Study (PIRLS) data from 2011 showed that school safety was an important factor associated with learner achievement in many countries (Martin, Foy, Mullis & O'Dwyer, 2013). The sense of security that comes from having minimal behavioural problems, and little or no concern about learner or educator safety at school, promotes a stable learning environment (Winnaar et al., 2018). The Gauteng Department of Education *Strategic Plan* (GDE, 2020) highlights the concerns regarding safety in their schools.

TIMSS 2019 asked educators to report on the characteristics of their schools' safety and discipline. Table 23 reports responses (agree a lot to the statement) from mathematics educators[44] about the characteristics of safe and orderly schools.

Overall, the responses show that most learners were not in schools characterised as safe and orderly. According to educators' responses, approximately a third of the learners were in schools located in safe neighbourhoods and where educators felt safe in the school. Educators were concerned about the behaviour of learners, reporting that only 15 percent behaved in an orderly manner, 14 percent of learners were respectful of educators and 11 percent respected school property.

Within the environment of low levels of safety and orderliness in schools, learners in no-fee schools were reported to be in more unsafe conditions relative to their counterparts in fee-paying schools. The differences on every characteristic were statistically significant.

Table 23: Educator responses, by percentage of learners, to the characteristics of safe and orderly schools

Characteristics	Percent learners in schools rated 'Agree a lot'		
	Gauteng	No-fee	Fee-paying
The school has clear rules about learner conduct	59	46*	69
The schools' rules are enforced in a fair and consistent manner	39	24*	51
The school is located in a safe neighbourhood	30	15*	42
I feel safe at this school	29	10*	43
The school's security policies and practices are sufficient	22	7*	33
The learners behave in an orderly manner	15	5*	23
The learners are respectful of educators	14	7*	18
The learners respect school property	11	2*	18

* Statistically significant achievement difference between categories.

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

44 Responses from science educators were similar.

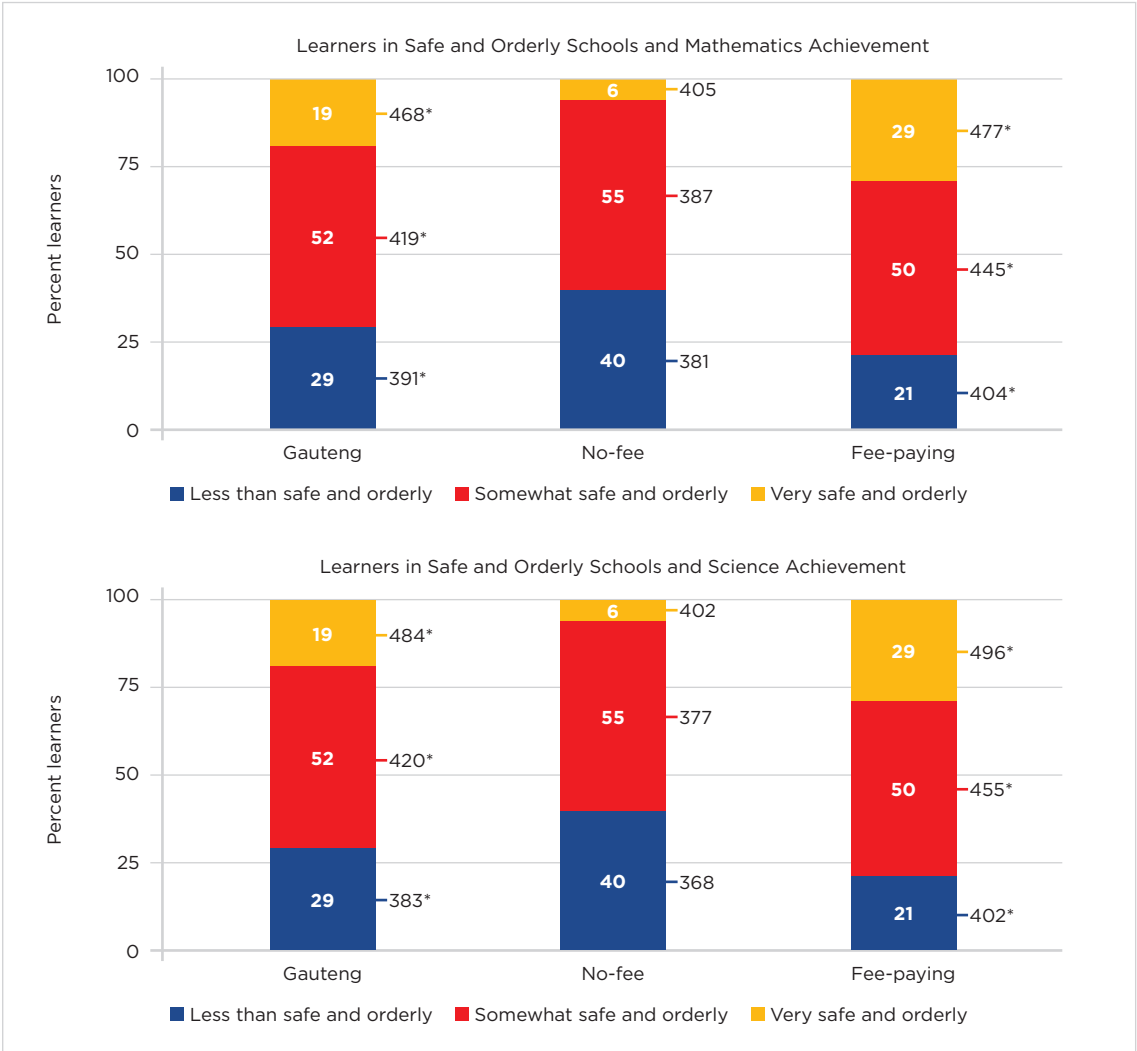
TIMSS 2019 used the eight characteristics to create a *Safe and Orderly School Scale*[45]. The scale was divided into three categories, with learners attending schools that were: 1) *very safe and orderly*, 2) *somewhat safe and orderly*, or 3) *less than safe and orderly*.

Figure 44 reports the relationship between the extent to which schools were safe and orderly, and learner achievement, by school fee status. Like the national statistics, only 19 percent of Gauteng learners attended schools categorised as very safe and orderly. This contrasts with the international average, where 48 percent of learners attended schools that were considered very safe and orderly.

Learners in schools reported to be very safe and orderly significantly outperformed learners in schools that were less than safe and orderly (468 versus 391 for mathematics and 484 versus 383 for science). This pattern was also apparent in fee-paying schools.

Only six percent of Gauteng learners in no-fee schools attended schools that were reported to be very safe and orderly, and perhaps due to the multiple disadvantages in schools, we did not observe a significant association between the level of school safety and orderliness and achievement.

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



* Statistically significant achievement difference between categories.

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

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

School discipline

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

Principals were asked to what extent the 11 behaviours in Table 24 were a problem among learners in their school. We report the percentage of learners attending schools that experienced these as 'severe problems'. The most severe problems reported were vandalism (29%), learners arriving late at school (25%) and theft (25%). There were significantly higher incidences of two discipline problems – vandalism and learners arriving late at school – in no-fee schools than in fee-paying schools.

Table 24: Principal responses, by percentage of learners, to learners' poor discipline in schools

Behaviours in school	Percent learners in schools rated 'severe problem'		
	Gauteng	No-fee	Fee-paying
Vandalism	29	46*	17
Arriving late at school	25	33*	18
Theft	25	31	21
Classroom disturbance	19	22	18
Intimidation or verbal abuse among learners	18	18	17
Absenteeism	17	22	14
Physical injury to other learners	10	11	9
Profanity	8	6	9
Intimidation or verbal abuse of educators or staff	4	6	3
Cheating	3	7	1
Physical injury to educators or staff	2	1	3

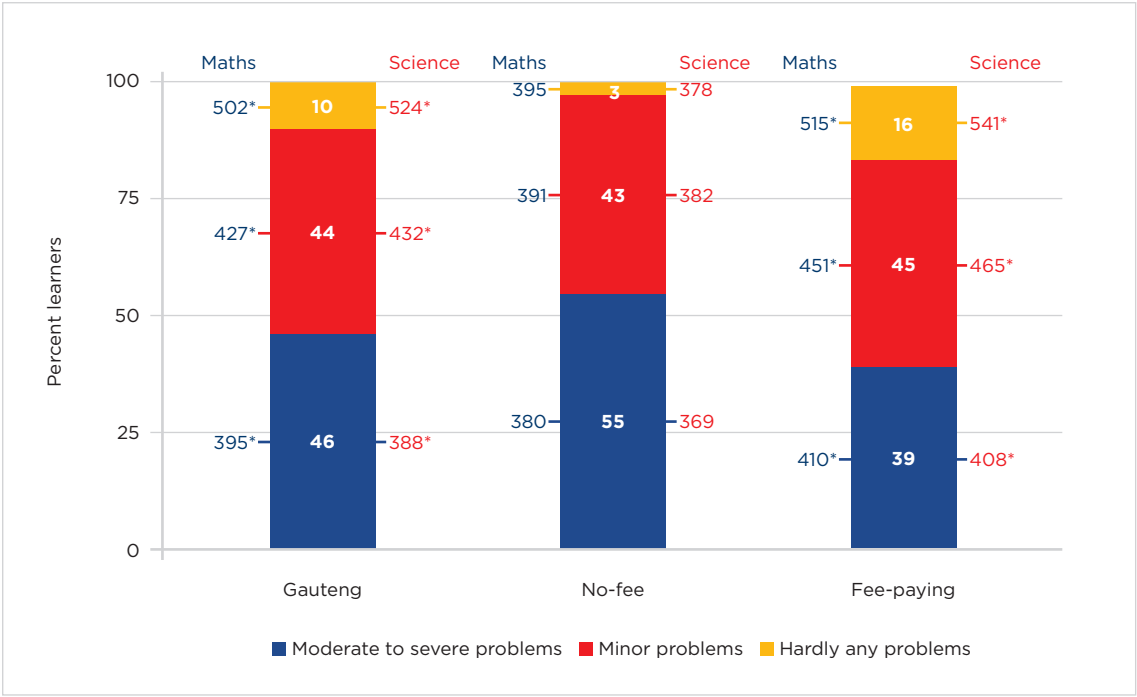
* Statistically significant achievement difference between categories.

Source: Authors' own calculations TIMSS 2019 South African (Gauteng) Grade 9 dataset.

TIMSS used these eleven behaviours to create a *School Discipline Scale*[46]. Three categories were included in the scale: 1) *moderate to severe* problems, 2) *minor* problems, and 3) *hardly any* problems.

Figure 45 reports the relationship between school discipline and achievement by school fee status. Forty-six percent of Gauteng Grade 9 learners experienced 'moderate to severe problems', in comparison with the international average of 11 percent and the South African average of 39 percent. For Gauteng and in fee-paying schools, learners who experienced hardly any problems or minor problems significantly outperformed learners in schools with moderate or severe problems. In no-fee schools, there was no association between the extent of discipline problems experienced, and learners' mathematics and science achievement. This is again probably due to the lack of achievement variation or the collinearity between school discipline and other school climate factors.

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 South African (Gauteng) Grade 9 dataset.

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

Incidences of bullying in schools

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

Gauteng Grade 9 learners reported on how often they experienced bullying behaviours (physical, verbal or through digital devices) at school. We report the percentage of learners who 'never or almost never' experienced bullying (Table 25). On average, 70 percent of learners hardly experienced verbal bullying, three-quarters hardly experienced physical bullying, and nine in ten learners hardly experienced any form of cyber bullying. The converse of this is that 30 percent did experience some form of verbal bullying, a quarter experienced physical bullying, and 12 percent experienced cyber bullying. This represents high levels of bullying behaviours in schools and may be reflective of the extent of bullying and violence in the communities that surround the schools.

The extent of bullying on all behaviours listed in Table 25 was significantly higher for learners in no-fee schools than in fee-paying schools.

Table 25: Percentage of learners who were never or almost never bullied, by school fee status

Behaviours	Percent learners in schools rated 'never or almost never bullied'		
	Gauteng	No-fee	Fee-paying
Verbal			
Insulted a member of my family	78	74*	81
Shared my secrets with others	76	71*	79
Refused to talk to me	70	63*	75
Spread lies about me	67	61*	71
Said mean things about my physical appearance	58	48*	64
Average for verbal bullying	**70**	**63**	**74**
Physical			
Made me do things I did not want to do	81	76*	84
Threatened me	83	78*	87
Physically hurt me	82	75*	86
Damaged something of mine on purpose	75	69*	80
Stole something from me	48	40*	54
Average for physical bullying	**74**	**68**	**78**
Cyber			
Shared embarrassing photos of me online	92	90*	94
Sent me nasty of hurtful messages online	84	79*	88
Shared nasty or hurtful things about me online	88	84*	91
Average for cyber bullying	**88**	**84**	**91**

* Statistically significant achievement difference between categories.

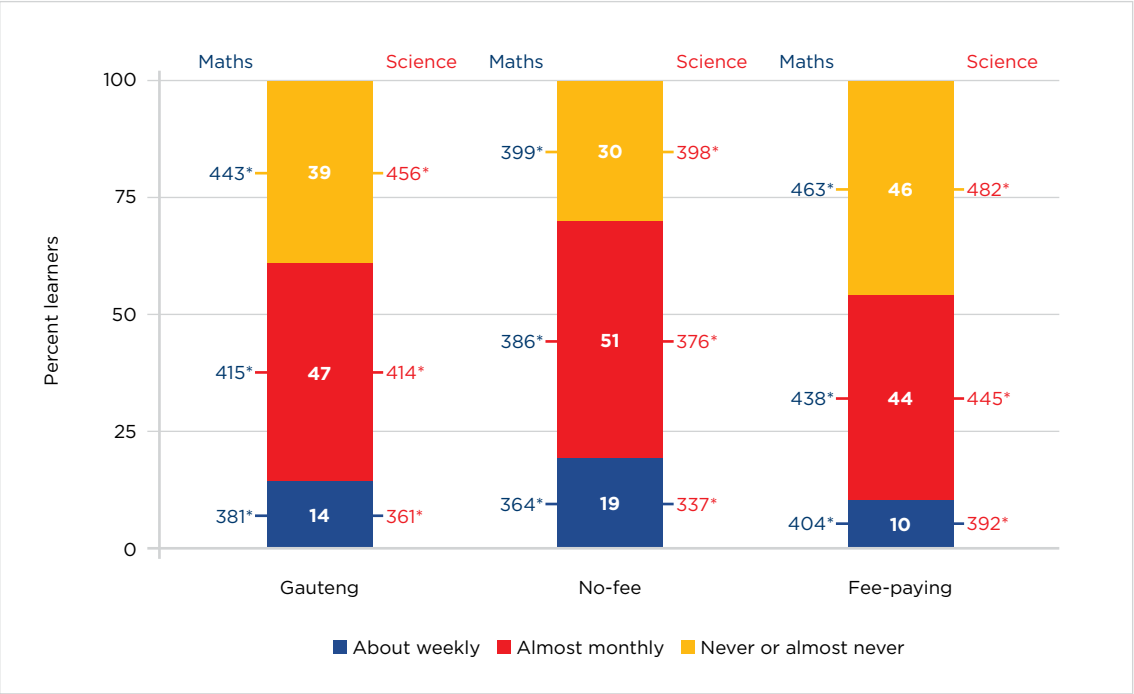
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

TIMSS 2019 used the 13 behaviours to create a *Learner Bullying Scale*[43]. The scale used three categories: 1) bullied *about weekly*, 2) bullied *almost monthly*, and 3) *never or almost never* bullied. Figure 46 reports the relationship between bullying and achievement by school fee status.

Gauteng learners reported higher levels of bullying than most TIMSS participating countries. Thirty-nine percent of learners reported 'never or almost never' being bullied, compared to the international average of 71 percent. This was however higher than the national average of 35 percent.

Learners who hardly experienced any form of bullying achieved significantly higher mathematics and science scores than learners who experienced bullying weekly (443 versus 381 for mathematics and 456 versus 361 for science). The same significant associations were observed in both no-fee and fee-paying schools.

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



* Statistically significant achievement difference between categories.

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

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

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

7.4. SUMMARY: SCHOOLS AS ENABLING LEARNING ENVIRONMENTS

Home to school socioeconomic continuities

Thirty-seven percent of Gauteng Grade 9 learners came from homes categorised as high SES, 34 percent as medium SES and 29 percent as low SES. Parents and society expect schools to equalise opportunities and level the playing field of educational success for learners from households with high levels of income poverty and low educational capital.

There was continuity of SES from homes to schools – just under half the learners in no-fee schools came from low-income households with less access to resources. Advantage begets advantage, and learners from more affluent households enter schools with better resources.

School characteristics

Learners attending Quintile 1, 2, 3 and 4 public as well as independent schools in Gauteng were at least 80 percent Black African. Black African learners made up two-thirds of the Quintile 5 cohort. Almost all White and Indian/Asian learners attended Quintile 5 or independent schools.

Three quarters of learners attended schools in big and medium cities and suburbs, 16 percent in small towns or villages, and six percent in remote rural areas. Learners attending schools in big and medium size cities and suburbs attained significantly higher mathematics and science achievement than those attending schools in small towns, villages or remote rural areas.

School climate: Emphasising academic success

A defining feature of a well-performing school is a positive school climate that emphasises and promotes academic success. Principals rated mathematics and science educators highly on aspects emphasising academic success but were less positive about parental and learner behaviours that emphasised academic success. Parental involvement and support for learning were rated significantly higher in fee-paying schools than in no-fee schools.

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

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

Another characteristic of a well-performing school is that it provides safe and orderly spaces for both learners and educators. One in five (21%) Gauteng learners attended schools rated as very safe and orderly. School discipline problems were prevalent, with only 10 percent of learners in schools characterised as having hardly any discipline problems. Learner bullying was widespread, as 60 percent of the learners reported that they experienced incidences of bullying in school at least once a month. There were significantly higher incidences of physical, verbal and cyber bullying behaviours in no-fee schools than in fee-paying schools.

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

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

CHAPTER EIGHT

CLASSROOMS: EDUCATORS, RESOURCES AND INSTRUCTIONAL PRACTICES

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

In this chapter we report on:

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

8.1. EDUCATORS

Preparation and experience

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

Table 26 describes the Gauteng educators by the demographics of gender, age, teaching experience, educational qualifications, subject specialisation and educators' job satisfaction levels by the percentage of learners taught.

Table 26: Percentage of learners taught by educators with each characteristic

	Percent learners taught by mathematics educators	Percent learners taught by science educators
Gender		
Taught by female educators	46	63
Taught by male educators	54	37
Educator age		
Less than 29 years	23	22
30-39 years	20	22
40-49 years	29	34
Over 50 years	28	21
Average teaching experience	14 years	14 years
Educational qualification		
Finished Grade 12	0	1
Finished Diploma	22	13
Finished First degree	56	59
Finished Honours or higher	21	28
Subject specialisation	90% of learners taught by educators with a specialisation in mathematics	88% of learners taught by educators with a specialisation in science
Educator satisfaction levels	65% of learners taught by educators who were very satisfied in their job	53% of learners taught by educators who were very satisfied in their job

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Just less than half of mathematics learners and close to two-thirds of science learners were taught by a female educator. There was a fairly normal age distribution of educators, suggesting that as older educators leave the education system there is a pipeline of new educators moving up to take their place. The average teaching experience of Gauteng Grade 9 mathematics and science educators was 14 years, compared to the international average of 16 years' experience.

The majority of learners were taught by mathematics (77%) and science (87%) educators with at least a Bachelor's degree qualification, compared with 96 percent of learners internationally. For both mathematics and science, there were no significant achievement differences between learners taught by educators with a degree qualification and learners taught by educators without a degree.

Ninety percent of mathematics learners and 88 percent of science learners were taught by educators who reported a subject specialisation. There were no significant achievement differences for learners taught by educators with or without a subject specialisation. We were unable to confidently corroborate educator qualifications and specialisations with other provincial data. The Sustainable Development Goals: South African Country Report 2019 stated that 91 percent of educators had the minimum required qualifications of either a three-year teacher's diploma or a three-year degree (StatsSA, 2019b). The profiles of mathematics and science educators in both no-fee and fee-paying schools were similar.

Educator professional development participation and future needs

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

Figure 47 reports the percentage of learners taught by mathematics and science educators in relation to their professional development participation and needs. The professional development programmes, largely, would have been coordinated by the provincial- and district-level education authorities. Most of the mathematics and science professional development activities that educators had attended related to content, curriculum, and assessment. Surprisingly, there were fewer activities related to integrating technology into instruction and addressing individual learner needs. An unexpected finding was the relatively lower level of professional development activities related to pedagogy or instruction, a key factor in improving educational achievement.

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

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

Professional activities	Mathematics		Science	
	Educators' participation in professional development	Educators indicating a need in professional development	Educators' participation in professional development	Educators indicating a need in professional development
Content	90	60	78	59
Curriculum	79	63	73	58
Assessment	77	68	65	67
Pedagogy/Instruction	64	72	50	64
Improving learners' critical thinking or problem-solving skills	61	88	50	80
Integrating technology into instruction	60	83	51	79
Addressing individual learner needs	52	82	44	74

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Educators were also asked when the professional development activities usually took place. Over 90 percent of activities took place outside school hours – after school, on weekends or during holidays. Therefore, the teaching and learning time seemed to generally be protected in Gauteng.

8.2. RESOURCES TO TEACH MATHEMATICS AND SCIENCE

Class size and achievement

According to the Personnel Administrative Measures (DBE, 2016), the ideal maximum Grade 9 class size is 37 learners. However, class sizes have increased in Gauteng due to high in-migration. For the period 2016 to 2021, the Gauteng province school enrolments increased by close to 100 000 due to in-migration of learners (GDE, 2020).

During the logistical planning of the TIMSS 2019 data collection in Gauteng, classes that were sampled to participate in the study submitted the names of all learners in that class. This was captured on the TIMSS WinW3S software. We captured the total number of learners as a variable onto the TIMSS 2019 dataset, which included learner and school information, as well as their mathematics and science achievement plausible values.

Table 27 reports the average TIMSS 2019 Grade 9 class sizes in Gauteng by the quintiles of public schools as well as for independent schools.

Table 27: Average class size (with standard deviation) for Gauteng, Quintiles 1-5 TIMSS sample

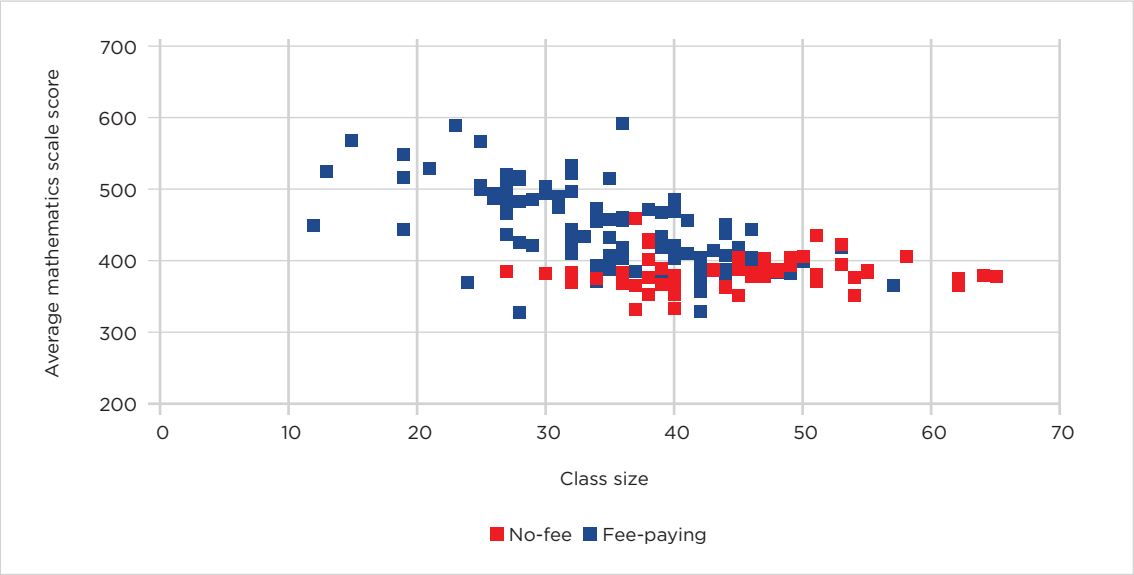
	Gauteng (SD)	Quintile					
		1 (SD)	2 (SD)	3 (SD)	4 (SD)	5 (SD)	Independent
Class size: number of learners	41 (9.7)	48 (9.1)	46 (8.3)	44 (7.5)	43 (7.1)	36 (7.0)	29 (8.6)

Source: Authors' own calculation from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

In Gauteng, the average TIMSS 2019 Grade 9 class size was 41 learners (compared to the South African TIMSS average of 51 learners). The TIMSS class sizes ranged from 15 to 65 learners. Quintile 1 to 4 schools had similar average class sizes, clustered around 45 learners per class, much higher than the prescribed average class size. Quintile 5 schools, with an average of 36 learners per class, and independent schools, with an average of 29 learners per class, had the smallest average class sizes. Thirty-six percent of learners attended classes with fewer than or equal to 37 learners, meaning that 64 percent attended classes with more than 37 learners.

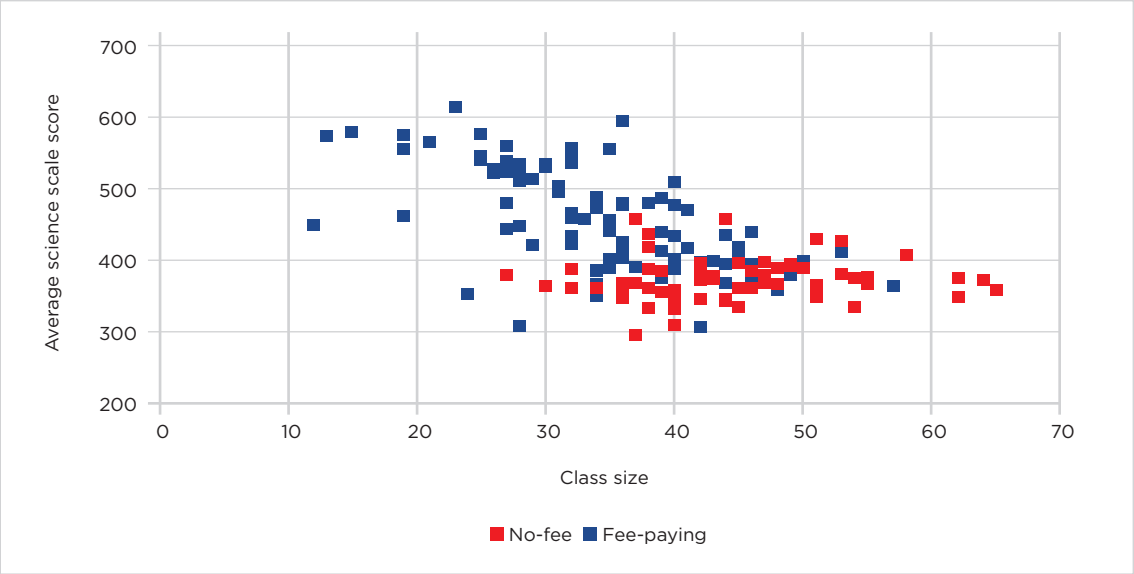
To explore the relationship between class size and achievement, we calculated the average mathematics and science achievement for each TIMSS class. Figure 48 and Figure 49 show the scatterplots of TIMSS 2019 class size and achievement for no-fee and fee-paying schools (see Reader's Guide). There was higher achievement variance in fee-paying schools than in no-fee schools.

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



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

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

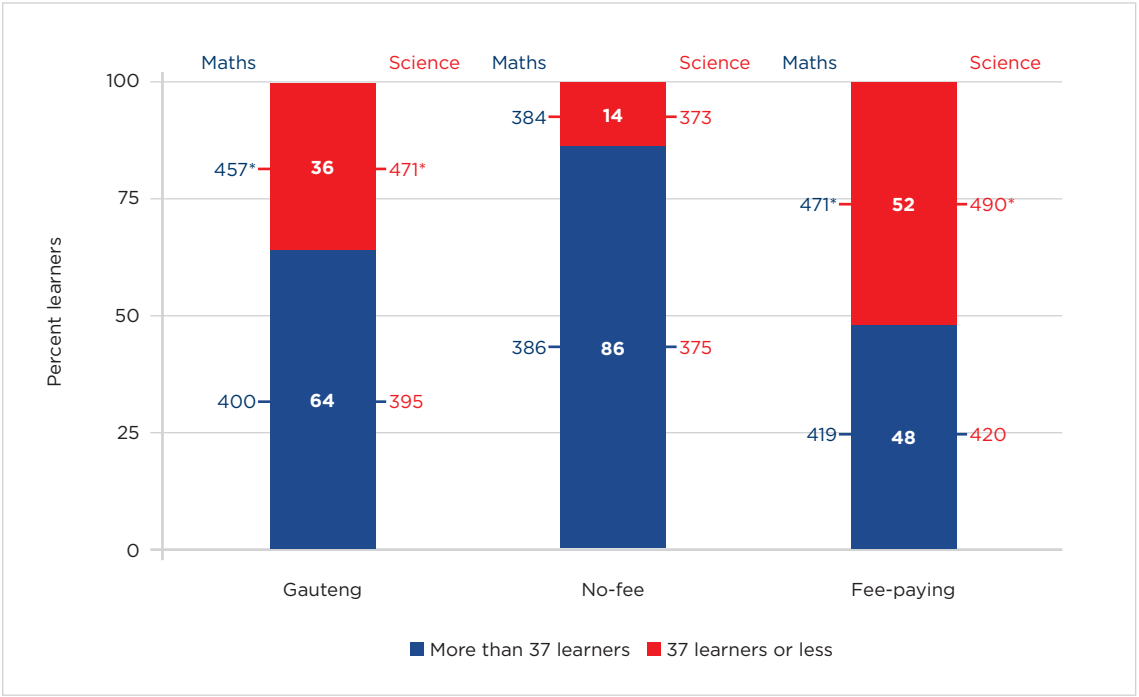


Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

We explored the relationship between class size and mathematics and science achievement further for the Gauteng province, and in no-fee and fee-paying schools. In the province, just over one-third of learners were in classes with less than 37 learners. The average class size in no-fee schools was 46 learners and only 14 percent of learners were in classes with less than 37 learners. These conditions are not optimal for promoting teaching and learning. In fee-paying schools, the average class size was 37 learners, and half of the learners (52%) were in classes with less than 37 learners.

Learners in classes with 37 learners or less scored significantly higher average mathematics and science achievement than those in classes with more than 37 learners (457 versus 400 for mathematics, and 471 versus 395 for science) (Figure 50). We observed the same pattern for learners in fee-paying schools. In no-fee schools, we did not observe any differences in achievement scores. This could be due to the multitude of factors that affect learning in no-fee schools as well as the low achievement variance between and within the two groups.

Figure 50: Percentage of learners by class size and achievement, by school fee status



* Statistically significant achievement difference between categories.

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

Resources and materials

The resources available in a school and its classrooms are expected to influence the quality of instruction, learning, and subsequently, achievement. Table 28 reports principals' rating of how instruction in their school was affected by the availability of mathematics and science resources.

According to the principal reports, more than half of Gauteng learners attended schools that were affected by shortages of educators with specialisations in mathematics and science. This is not in line with what educators reported: that 90 percent had mathematics specialisations and 88 percent had science specialist qualifications (Table 28). Around half the learners attended schools that experienced substantial shortages in science equipment and materials for experiments (53%).

Table 28: Percentage of learners affected substantially[48] by a shortage of the following factors

Resources for mathematics	Percent learners affected substantially	Resources for science	Percent learners affected substantially
Calculators for mathematics instruction	61	Calculators for science instruction	52
Educators with specialisation in mathematics	58	Educators with specialisation in science	52
Concrete objects or materials to help learners understand quantities or procedures	47	Science equipment and materials for experiments	53
Adequate instructional materials and supplies are a problem in mathematics[49]	43	Adequate instructional materials and supplies are a problem in science	47
Library resources relevant to mathematics instruction	39	Library resources relevant to science instruction	40

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Textbooks and workbooks

One of the key teaching and learning resources in the classroom are textbooks and workbooks, especially in no-fee schools. The government has invested in the provision of mathematics and science textbooks and workbooks to learners. Figure 51 reports the availability of Grade 9 mathematics textbooks and workbooks, and Figure 52 reports access to these resources for science.

Learners reported relatively good access to mathematics text resources, with 89 percent either owning or sharing a mathematics textbook, and 93 percent either owning or sharing a mathematics workbook. This aligns with the figures in the School Monitoring Survey 2017/2018 (DBE, n.d.) which reported that nationally, 83 percent of Grade 9 learners had access to a mathematics textbook. This was similar for science, with 91 percent of learners either owning or sharing a science textbook, and 87 percent either owning or sharing a science workbook[50].

Learners in fee-paying schools had slightly greater access to their own mathematics and science textbooks and workbooks than learners in no-fee schools. It is however, somewhat concerning that 13 percent of Gauteng learners reported that they did not have science workbooks.

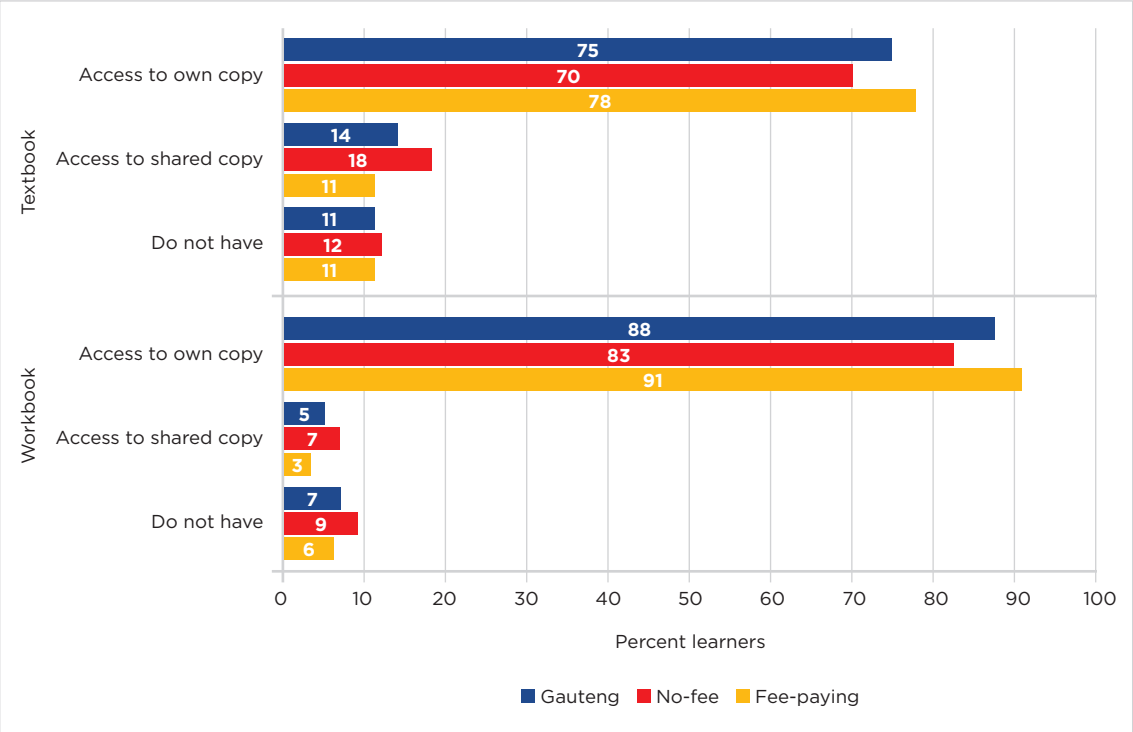
A small number of learners reported that they had neither a workbook nor a textbook: three percent for mathematics and five percent for science.

48 Response by principal was 'Some' or 'A lot' which were combined to form 'Substantial'.

49 This item is from the Educator Questionnaire and responses 'Moderate' and 'Serious' were combined to form 'Substantial'.

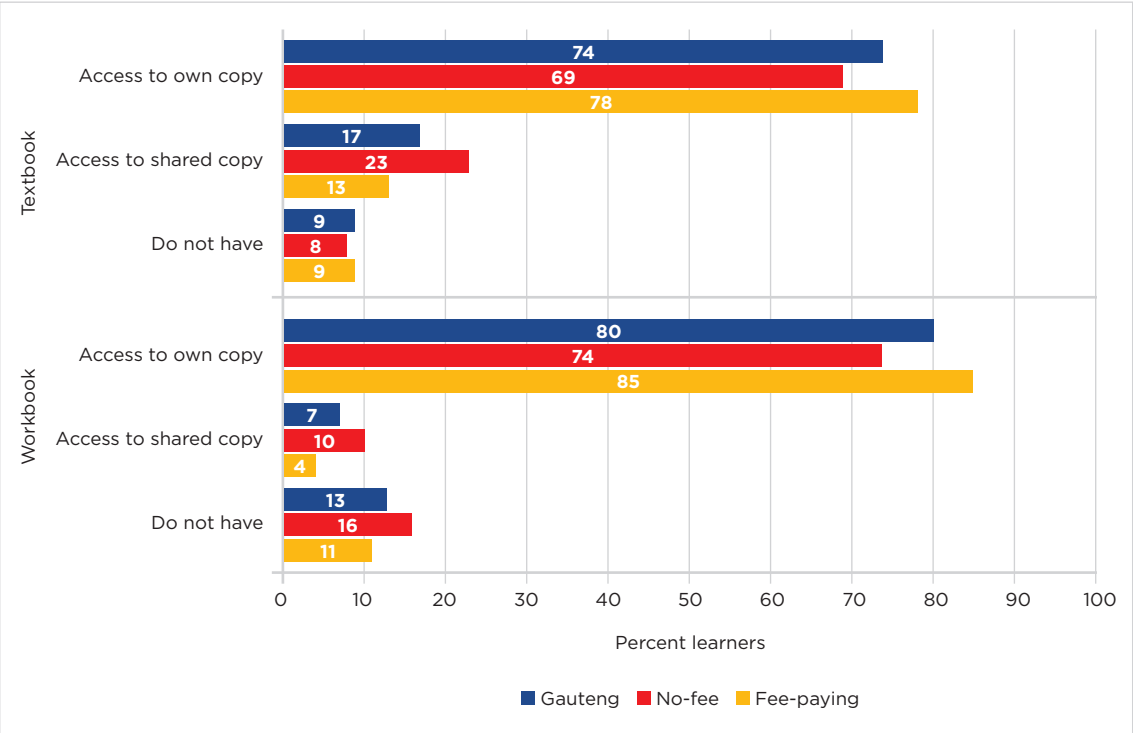
50 The DBE provides mathematics and language workbooks to schools.

Figure 51: Percentage of learners with access to mathematics textbooks and workbooks, by school fee status



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

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



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

Next, we combined the categories of learners sharing workbooks or textbooks with classmates and those who did not have these resources, to establish the association with achievement for those who had their own textbooks and workbooks (Table 29).

For the Gauteng province, in no-fee and fee-paying schools, learners who had their own mathematics or science textbook or workbook achieved significantly higher mathematics and science scores than those who shared or did not have workbooks or textbooks.

Table 29: Association between access to textbooks and workbooks, and achievement

	Gauteng achievement (SE)	No-fee achievement (SE)	Fee-paying achievement (SE)
Learner access to mathematics textbook			
Access to own copy	430* (3.4)	386 (3.6)	457* (4.5)
Share or do not have	395 (3.8)	384 (4.7)	405 (5.9)
Learner access to mathematics workbook			
Access to own copy	425* (3.1)	387* (3.2)	450* (4.4)
Share or do not have	386 (4.1)	376 (5.0)	401 (7.1)
Learner access to science textbook			
Access to own copy	436* (4.3)	381* (5.0)	471* (5.5)
Share or do not have	383 (5.0)	361 (4.9)	405 (8.5)
Learner access to science workbook			
Access to own copy	434* (4.0)	381* (4.7)	467* (5.4)
Share or do not have	374 (4.5)	358 (5.6)	394 (6.9)

* Statistically significant achievement difference between categories.
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.

8.3. CLASSROOM INSTRUCTIONAL PRACTICES

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

Educators' instructional clarity

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

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

Table 30 reports on strategies that mathematics and science educators reported they used in teaching their classes. The TIMSS questionnaire also asked learners to rate their educators' instructional clarity on a number of statements, to establish the Instructional Clarity Index (Table 31).

Educators rated their instructional clarity activities in the classroom very highly. For example, according to educator reports, 93 percent of mathematics learners and 95 percent of science learners experienced them 'linking new content to learners' prior knowledge'. However, learners were more modest in their rating. For example, for the same item 'my educator links new lessons to what I already know', only 44 percent of mathematics learners and 46 percent of science learners agreed a lot with the statement.

On average, 50 percent of mathematics learners and 53 percent of science learners (similar to the South African averages) reported that their educators provided high clarity of instruction. The comparable international averages were 46 percent for mathematics and 49 percent for science, respectively.

Table 30: Percentage of learners by educators' rating of their instructional clarity

Elements of Instructional Clarity	Percent of learners' experience of strategy for 'half or more lessons'	
	Mathematics	Science
Cognitive activation		
Ask learners to explain their answers	84	88
Relate the lesson to learners' daily lives	70	80
Ask learners to decide their own problem-solving procedures	72	64
Ask learners to complete challenging exercises	62	65
Bring interesting materials to class	58	62
Supportive learning climate		
Link new content to learners' prior knowledge	93	95
Encourage learners to express their ideas in class	88	84
Encourage classroom discussion among learners	73	68

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Table 31: Learners' rating of educators for Instructional Clarity Index for mathematics and science

Elements	Percent of learners who 'agree a lot'	
	Mathematics	Science
My teacher explains a topic again when we don't understand	67	63
My teacher is good at explaining mathematics/science	58	63
I know what my teacher expects me to do	57	57
My teacher does a variety of things to help us learn	57	57
My teacher has clear answers to my questions	49	55
My teacher is easy to understand	45	52
My teacher links new lessons to what I already know	44	46
Instructional Clarity Index	**50**	**53**

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

TIMSS created an *Instructional Clarity Scale* based on learner responses to the seven items[51]. The scale comprised three categories: 1) *low clarity* of instruction, 2) *medium clarity* of instruction, and 3) *high clarity* of instruction. For the Gauteng province, as well as in no-fee and fee-paying schools, there were no discernible patterns between mathematics and science achievement and the extent of instructional clarity, possibly because educators and learners were over-rating and providing socially desirable answers.

Learner behaviour during mathematics lessons

Good classroom management and having learners pay attention and focus on the lessons, help to create a classroom environment conducive to learning. Learners were asked a set of six questions about the frequency of disorderly behaviour during mathematics lessons, including whether learners listened to what the educator said, how often the classroom was too disorderly for learners to work well, and how often educators had to tell learners to follow the classroom rules. Table 32 reports the percentage of learners who experienced this behaviour in almost every lesson.

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

A third of the learners reported that educators had to appeal to the class for order, to be quiet and listen, and 22 percent reported that it was too disorderly to work well in almost every lesson.

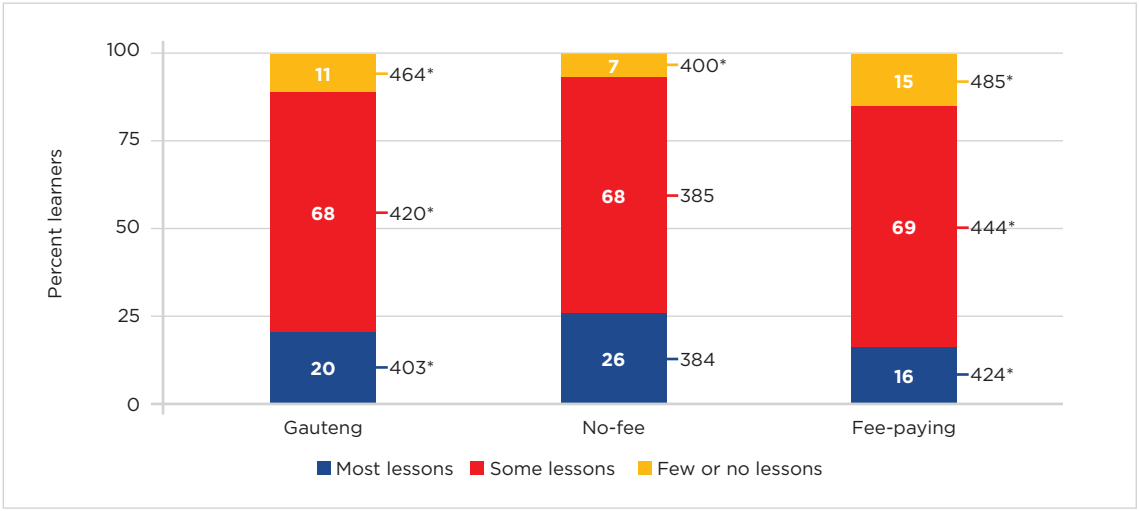
Table 32: Elements that constitute disorderly behaviour during mathematics lessons

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	35
There is disruptive noise	32
Learners don't listen to what the educator says	31
My educator has to wait a long time for learners to quiet down	29
Learners interrupt the educator	28
It is too disorderly for learners to work well	22

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

These six responses were combined into a *Disorderly Behaviour during Mathematics Lesson Scale*[52]. There was a higher level of disorderly behaviour in Gauteng mathematics classrooms compared to other countries. Twenty percent of Gauteng Grade 9 learners experienced disorderly behaviour in most lessons, compared to the international average of 13 percent and the South African average of 19 percent. Internationally, and in most countries, there was a negative association between the frequency of disorderly behaviour and average mathematics achievement. The same pattern was found in Gauteng. Learners in classes with disorderly behaviour in a few lessons scored 464 points on average, in comparison with 403 points for learners who experienced disorderly behaviour in most lessons (Figure 53). This robust association was also observed in both the no-fee and fee-paying schools in the province.

Figure 53: Percentage of learners experiencing disorderly behaviour during mathematics lessons, and mathematics achievement, by school fee status



* Statistically significant achievement difference between categories.

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

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

Emphasis on science investigation and experiments

The first aim of the Natural Science Curriculum is that learners must 'do' science, which involves conducting investigations, analysing problems, and using practical processes and skills in evaluating solutions (DBE, 2011b). Basic resources to teach science in a practical manner are essential, and schools with a laboratory and/or science equipment are more effective in providing a quality science teaching and learning experience.

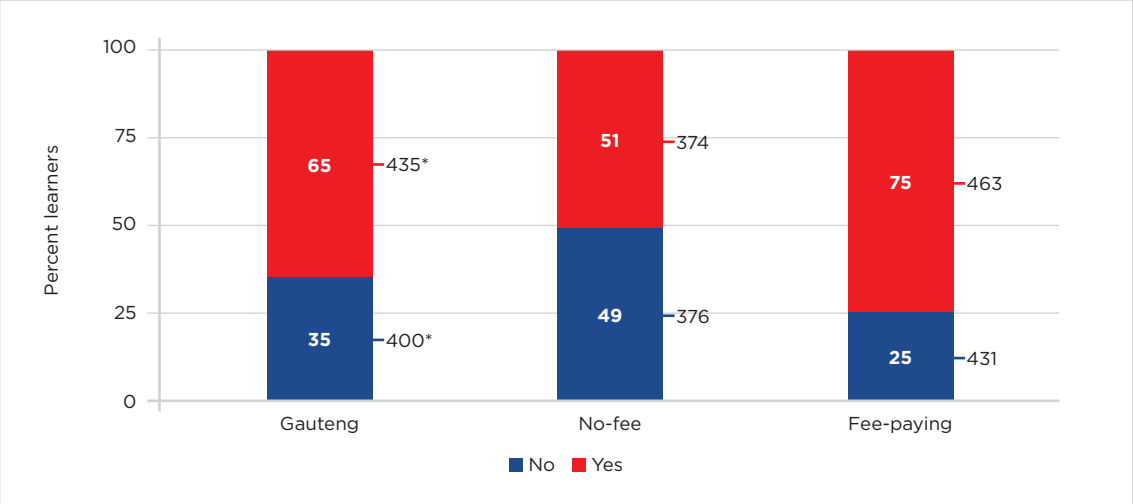
Schools with science laboratories

Using principals' responses, Figure 54 reports the availability of a laboratory for learners to conduct science experiments, and the relationship with their science achievement.

In Gauteng, close to two-thirds of the learners were taught in schools that principals reported had a science laboratory. However, according to the 2020 National Education Infrastructure Management System (NEIMS) report, only 33 percent of all schools in the province had a laboratory (DBE, 2020a). We were unable to corroborate this with figures for secondary and primary schools. When the TIMSS 2019 data were disaggregated by school type, half the learners in no-fee schools and three-quarters of the learners in fee-paying schools were in schools with a science laboratory.

In Gauteng, learners attending schools with a science laboratory achieved significantly higher science scores (435) than those attending schools that did not have a laboratory (400). We did not observe the same association when disaggregated by school fee status.

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 (Gauteng) Grade 9 dataset.

Instructional activities related to science investigation

Gauteng Grade 9 science educators were asked how often they conducted certain instructional activities (Table 33) that emphasise science investigation. According to the science educator reports, half the learners watched educators demonstrate experiments and 43 percent conducted experiments themselves.

Table 33: Percentage of learners, according to science educators, who were asked to do the following in science lessons:

Science Investigation Instructional Activities	Percent learners who experienced science investigation in 'half the lessons or more'
Observe natural phenomena and describe what they see	63
Use evidence from experiments or investigations to support conclusions	54
Present data from experiments or investigations	53
Interpret data from experiments or investigations	52
Watch me demonstrate an experiment or investigation	48
Design or plan experiments or investigations	44
Conduct experiments or investigations	43
Do field work outside of class	20

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

8.4. COMPUTERS IN EDUCATION AND INSTRUCTION

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

Computers in the home

Around two-thirds of the learners reported having access to a computer (or tablet), and over half reported having an internet connection at home (see Chapter 5). When compared with the findings of the 2019 General Household Survey (GHS), the learners who participated in TIMSS may have over-reported the availability of these assets at home. GHS 2019 reported that 31 percent of households in Gauteng had a computer/laptop and 15 percent had access to the internet at home (StatsSA, 2020b). Learners who reported access to computers at home achieved significantly higher mathematics and science scores than learners without these resources (Table 34).

Table 34: Availability of a computer or tablet at home and achievement

Subject	Gauteng			
	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	65	434* (3.8)	35	397 (3.0)
Science	65	441* (4.6)	35	389 (4.0)

* Statistically significant achievement difference between categories.

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

Computer access in schools

The number of computers available for use in Gauteng Grade 9 classes, as reported by principals, is shown in Table 35. Sixty-five percent of Grade 9 learners were in schools with no access to computers, compared to 60 percent for South Africa. While slightly more learners in fee-paying schools had access to computers than learners in no-fee schools (41% in fee-paying schools versus 27% in no-fee schools),[53] when we further compare the number of computers available in the classroom, there were differences. Eighteen percent of learners in no-fee schools, compared with 28 percent in fee-paying schools, attended schools with more than 20 computers available for Grade 9 classes to use.

Table 35: Percentage of learners with access to computers (including tablets) in Grade 9 classes

	Gauteng	No-fee	Fee-paying
0 computer	65	73	59
1-10 computers	8	7	9
11-20 computers	3	2	4
21-30	6	3	9
More than 30 computers	18	15	19

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

While one-third of learners had access to computers in their Grade 9 classes, as is evident in the next section, the use of computers for instruction was limited.

Computer access and use in mathematics and science classrooms

Mathematics and science educators responded to whether Gauteng Grade 9 learners had access to computers in their mathematics and science lessons. According to educator reports, 15 percent of mathematics learners and eight percent of science learners had access to computers for their lessons (Table 36). Learners who had access to computers for science lessons achieved significantly higher science achievement scores than those who did not have access.

Table 36: Percentage of learners with access to computers for Grade 9 mathematics and science lessons, and achievement

Subject	Gauteng			
	Percent Yes	Achievement (SE)	Percent No	Achievement (SE)
Mathematics	15	434 (14.8)	85	418 (4.0)
Science	8	517* (18.9)	92	415 (4.6)

Source: TIMSS 2019 South African (Gauteng) Grade 9 dataset.

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

53 According to the NEIMS 2020 report, in Gauteng 81 percent of schools have a computer centre and 64 percent of schools have internet connectivity for teaching and learning purposes.

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

Educator characteristics

The average teaching experience of Gauteng mathematics and science Grade 9 educators was 14 years. Seventy-seven percent of mathematics learners and 87 percent of science learners were taught by mathematics and science educators who reported at least a Bachelor's degree qualification, compared with 96 percent of educators internationally. While 90 percent of mathematics learners and 88 percent of science learners were taught by educators who reported a subject specialisation, principals reported that over half the learners were affected by educators' lack of specialisation in mathematics and science.

Educator professional development

Most of the mathematics and science professional development activities attended by educators related to curriculum, content and assessment. An unexpected finding was the lower level of professional development activities related to pedagogy or instruction, how to integrate technology into instruction, and addressing learners' needs.

Teaching and learning time were generally protected in Gauteng, with over 90 percent of professional development activities taking place outside school hours (i.e. after school, on weekends or during school holidays).

Class size and achievement

The average Gauteng TIMSS Grade 9 class size was 41 learners, with class sizes ranging from 15 to 65 learners. The average class size in no-fee schools was 46 learners, and only 14 percent of learners were in classes with less than 37 learners. Quintile 5 schools had an average class of 36 learners and independent schools 29 learners. About half the learners in fee-paying schools were in classes with more than 37 learners.

Provincially and in fee-paying schools, learners in classes with 37 learners or less scored significantly higher average mathematics and science achievement than those in classes with more than 37 learners.

Textbooks and workbooks

Gauteng learners had relatively good access to their own mathematics textbooks (75%) and workbooks (88%) as well as to their own science textbooks (74%) and workbooks (80%). Learners in fee-paying schools had slightly higher access to mathematics and science textbooks and workbooks than learners in no-fee schools.

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

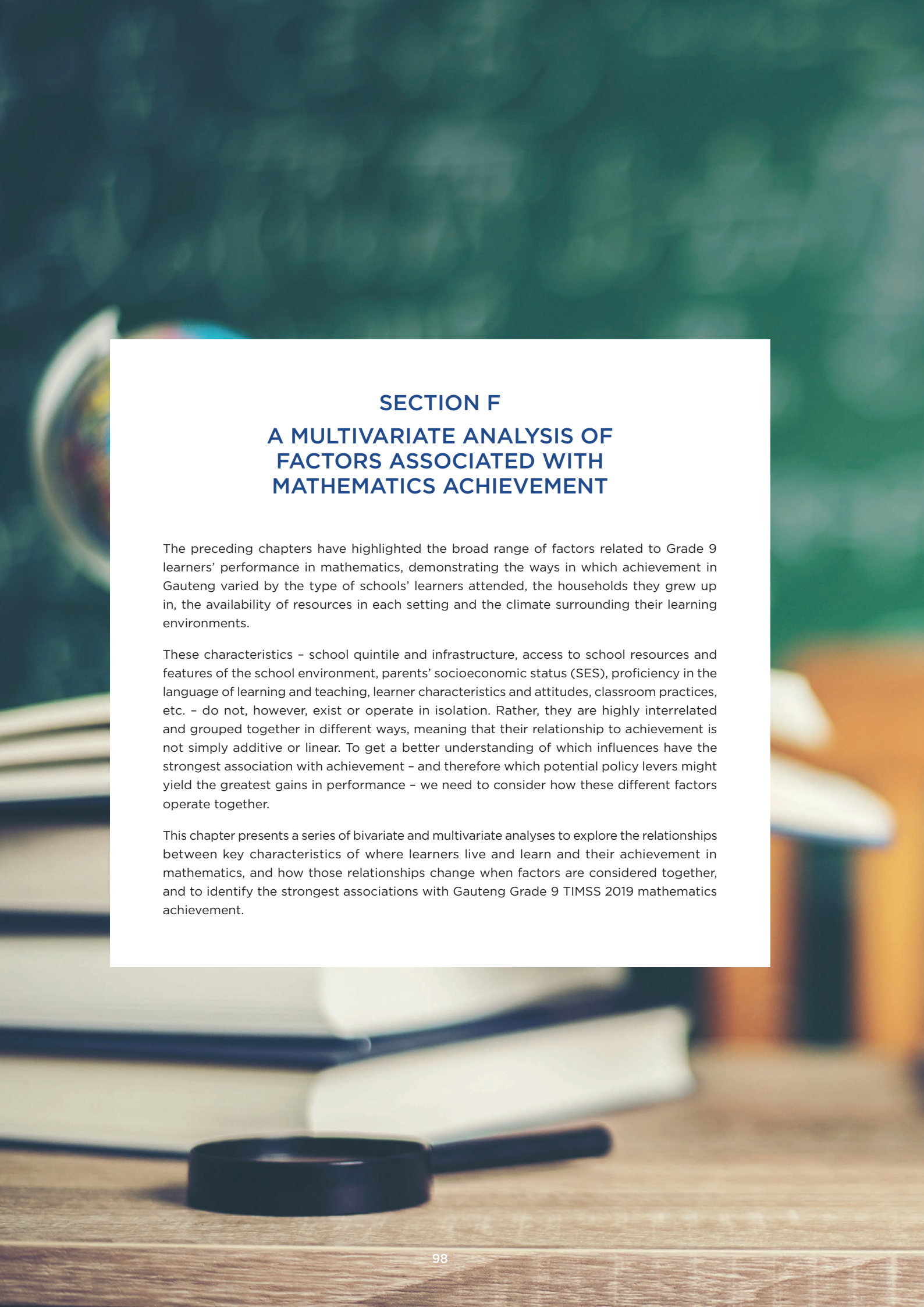
Science investigations and experiments

According to the principal reports, about two-thirds of learners attended schools with a science laboratory. Learners in schools with a science laboratory (a useful proxy for school resources) achieved significantly higher science scores than those attending schools that did not have a laboratory.

Computers in education and instruction

The availability and usage of computers for instruction in Grade 9 classes was surprisingly low in Gauteng. According to principal reports, 18 percent of learners in no-fee schools, compared with 28 percent of learners in fee-paying schools, had more than 20 computers available for the Grade 9 class to use.

The next section of the report presents a series of multivariate analyses (refer to Reader's Guide) 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 Grade 9 learners' performance in mathematics, demonstrating the ways in which achievement in Gauteng varied by the type of schools' learners attended, the households they grew up in, the availability of resources in each setting and the climate surrounding their learning environments.

These characteristics – school quintile and infrastructure, access to school resources and features of the school environment, parents' socioeconomic status (SES), proficiency in the language of learning and teaching, learner characteristics and attitudes, classroom practices, etc. – do not, however, exist or operate in isolation. Rather, they are highly interrelated and grouped together in different ways, meaning that their relationship to achievement is not simply additive or linear. To get a better understanding of which influences have the strongest association with achievement – and therefore which potential policy levers might yield the greatest gains in performance – we need to consider how these different factors operate together.

This chapter presents a series of bivariate and multivariate analyses to explore the relationships between key characteristics of where learners live and learn and their achievement in mathematics, and how those relationships change when factors are considered together, and to identify the strongest associations with Gauteng Grade 9 TIMSS 2019 mathematics achievement.

CHAPTER NINE

FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

9.1. AN OVERVIEW OF THE APPROACH USED

Building on the previous chapters, which explored the associations between individual, family and school-level characteristics, and learner achievement in mathematics, the analyses presented in this chapter focus predominantly on those correlations already shown to be significant. In doing so, we aim to present a parsimonious model of the characteristics associated with TIMSS 2019 mathematics attainment for Gauteng Senior Phase (Grade 9) learners. 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.

Basic associations

For completeness of building the model, we summarise the bivariate analyses presented in the previous chapters. The first set of regressions summarises the basic, 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 the two variables, such as language proficiency and achievement, but reports the 'effect' in terms of the average difference in TIMSS 2019 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[54] of each predictor variable as already defined – e.g. 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 two groups, rather than just chance variation across the two samples, it is statistically significant.

Grouped multivariate associations

The second set of regressions consider groups of characteristics, for example individual-level characteristics, indicators of household SES, factors describing the educator and their classroom and the principal and their school to explore in more detail how different sets of influences operate when considered jointly, given that this 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 the learner experiences. For example, learners with individual access to workbooks are also more likely to have sole use of a textbook. At the same time, these learners are less likely to be in classrooms where instruction is affected 'a lot' by a shortage of resources. Individually, each of these classroom aspects are important for achievement, but because they are themselves related, when their impact is considered jointly, the relationship between each single contributor and performance will typically be less. By looking at the relative contributions of each factor in a single model, we are better able to understand how different features of each context are related and start identifying which factors matter most.

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

Full multivariate model

The final analysis presents a single regression model with all influences on achievement considered together to identify the factors associated with achievement. This last step in our multivariate approach attempts to 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 and textbooks, mathematics-specific teaching aids – as well as the school's overall quintile ranking. Features of the different context areas are linked together in certain ways and so too are the contexts themselves. Because learning takes place within these intertwined contexts, it is only by understanding their influence altogether that we can properly identify the factors most associated with gains in learner performance.

Statistical analysis

All statistical analyses were performed using Stata 14.2 (StataCorp, 2015), using the package 'repest' (Avvisati & Keslair, 2014) developed by the Organisation for Economic Co-operation and Development (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.[55] The package also allows for analyses of datasets with plausible values (multiple imputed variables) ensuring both correct point estimates and standard errors are reported. Where plausible values are used, the average estimator across plausible values is reported and the imputation error is added to the variance estimator.

9.2. BIVARIATE ASSOCIATIONS

The following tables report the results from a series of bivariate regressions between Gauteng Grade 9 learners' mathematics achievement and measures of the learners' characteristics, features of their home environment and the school they attended shown to significantly correlate with achievement in the preceding chapters. The coefficients show the basic association between each individual variable and attainment without including any other measures in the model. The percentage of the observations for each variable is included in this model.

School quintile rank

Table 37 shows the basic association between school quintile and mathematics achievement and the coefficient (i.e. the average difference in TIMSS mathematics points for learners in each school quintile when compared to those in Quintile 1). 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 Quintile 2 schools scored five points lower than those in Quintile 1 schools (383 versus 388), and those in Quintile 3 schools scored three points lower (385 versus 388) compared to learners in Quintile 1 schools. Despite these small differences in average achievement scores, there were no significant differences between learners in Quintile 2 or 3 schools compared to those in Quintile 1 schools. Learners in both Quintile 4 and 5 schools did, however, perform significantly higher than those in Quintile 1 schools: 408 versus 388 points (a difference of 20 points) and 462 versus 388 points (a difference of 74 points), respectively.

The school quintile characteristic accounted for 24 percent of variance in Gauteng Grade 9 mathematics achievement.

55 Specific command for TIMSS was written by the package author, Francesco Avvisati at the OECD (personal communication with one of the report's authors, Dr Kathryn Isdale).

Table 37: Basic associations between school quintile rank and achievement

School Quintile	Coeff.	SE	Sig.	Percent
Quintile: (Ref = Q1)				**11**
Q2	-5	(9.1)		14
Q3	-3	(8.7)		17
Q4	20	(9.2)	*	21
Q5	74	(10.7)	***	27

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

Notes: Eleven percent of learners in Gauteng are in independent schools. Independent schools were not part of the provincial sampling methodology used and are not included in analyses presented above.

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

Household characteristics

The home environment is an important developmental context for learners, both in terms of household characteristics, such as SES and the availability of resources, but also with respect to the support parents can provide for their children's homework.

In Gauteng, Grade 9 learners from middle SES homes scored, on average, 56 points lower than those from high SES households, while those in low SES homes scored an average of 70 points lower. All achievement scores were statistically different from each other (see Table 38).

Parents' own educational capital – measured here as the level of difficulty parents had in understanding the Language of Learning and Teaching (LoLT) in the learners' school and in helping with schoolwork – were also strongly associated with learner achievement. Compared to learners whose parents never experienced problems understanding the LoLT, those whose parents sometimes did, scored, on average, 43 points lower; while those whose parents always had difficulties with the LoLT scored around 64 points lower. Similarly, learners whose parents never found their children's schoolwork content too difficult scored, on average, 15 points higher than those whose parents sometimes did, and 48 points more than those whose parents frequently struggled helping with their child's schoolwork.

Table 38: Basic associations between characteristics of the household and achievement

Household Characteristics	Coeff.	SE	Sig.	Percent
Household SES indicator: (Ref = High)				**37**
Middle	-56	(5.2)	***	34
Low	-70	(5.8)	***	29
Parents have difficulties understanding LoLT: (Ref = Never)				**48**
Sometimes	-43	(3.5)	***	34
Always/Almost always	-64	(4.0)	***	17
Schoolwork is too difficult for parents: (Ref = Never/Almost never)				**42**
Sometimes	-15	(2.5)	***	45
Always/Almost always	-48	(4.0)	***	13

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

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

Individual-level characteristics

In line with gender differences reported earlier (see Figure 26), girls' mathematics scores were, on average, six points higher than boys. This difference was statistically significant. Learners who were overage for the grade scored significantly lower than those who were the correct age: those who were overage by up to 12 months scored, on average, 53 points less, while those who were overage by more than a year scored 84 points lower.

Learner proficiency in the language of the test was also significantly related to mathematics achievement, with those who always or almost always spoke the language of the test at home scoring 55 points higher than those who spoke the language of the test at home sometimes, and 64 points higher than those who never did.

Table 39: Basic associations between characteristics of the individual and achievement

Individual-level Characteristics	Coeff.	SE	Sig.	Percent
Girl	6	(2.8)	*	55
Age bands: (Ref = Correct age)				**79**
Overage by up to 12 months	-53	(3.9)	***	14
Overage by more than 12 months	-84	(4.9)	***	7
Language proficiency: Speak language of test at home: (Ref = Always/Almost always)				**39**
Sometimes	-55	(4.8)	***	55
Never	-64	(6.1)	***	6

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

Learner attitudes to learning

Learners' own feelings about their ability in mathematics and its importance were also significantly associated with their achievement. Learners who were very confident in their own abilities scored, on average, 72 points more than those who were somewhat confident in their abilities, and an average of 98 points more than those who were not confident at all.

There were similar significant, but markedly smaller, associations between learners who reported that they 'very much like learning mathematics' compared to those who reported liking it less. There was also a small, marginally significant difference of six TIMSS points between learners who reported strongly valuing mathematics and those who valued it less.

Table 40: Basic associations between learner attitudes and mathematics achievement

Learner Attitudes	Coeff.	SE	Sig.	Percent
Learner confident in mathematics: (Ref = Very confident)				**8**
Somewhat confident	-72	(6.8)	***	38
Not confident	-98	(7.3)	***	54
Learner values mathematics: (Ref = Strongly values)				**69**
Somewhat values/Does not value	-6	(3.6)	†	31
Learner likes mathematics: (Ref = Very much likes)				**33**
Somewhat likes	-17	(3.9)	***	44
Does not like	-16	(5.1)	**	23

Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10
Notes: Only 4% of learners reported 'not valuing' mathematics and this category is collapsed into the 'somewhat value' group.

Educator and classroom characteristics

Learner access to their own workbook or textbook was found to be an important predictor of achievement in mathematics. Learners who shared or did not have access to their own workbook scored, on average, 39 points lower than those who had their own workbook. A similar association was found between learners with sole access to a textbook, who scored an average of 35 points higher than those who did not have sole access.

Where educators reported that instruction in lessons was affected by mathematics-specific resource shortages, the average difference in learner achievement, between learners affected or not, was 89 points.

There was also a clear association between the number of learners in a mathematics class and achievement. The nearly two-thirds of learners (64%) taught in classes of over 37 learners scored, on average, 57 points lower than those who were in smaller teaching groups.

Just over three-quarters (77%) of Grade 9 Gauteng learners were taught by educators who reported having a Bachelors-level, or higher, qualification. These learners scored an average of 22 points more than learners taught by educators with lower-level qualifications. There was no significant association between achievement in mathematics and whether the learner was taught by an educator who reported a specialisation in mathematics. Note, however, that nearly all educators (95%) reported such a specialisation.

There was a small, significant association between the clarity with which educators conveyed the mathematics content and learner mathematics achievement. Learners taught in classes in which educators conveyed the content of the mathematics curriculum with moderate clarity scored, on average, seven points lower than those where instructional clarity was reported to be high.

Finally, in terms of educator and classroom characteristics, the presence of disorderly behaviour during mathematics lessons was strongly and significantly associated with achievement: learners in classrooms where disorderly behaviour was reported as present in few or no lessons, scored an average of 44 points more than those where such behaviour was present in some lessons, and 61 points more than those where learners experienced disruptive behaviour in most lessons.

Table 41: Basic associations between educator and classroom characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.	Percent
Learner does not have own workbook	-39	(4.3)	***	12
Learner does not have own textbook	-35	(4.7)	***	25
Shortage of mathematics resources: (Ref = Instruction not affected)				**10**
Affected/Affected a lot	-89	(11.2)	***	90
Instructional materials and supplies: (Ref = Not/Minor problem)				**57**
Moderate/Serious problem	-42	(6.4)	***	43
Class size: Over 37 learners	-57	(8.0)	***	64
Educator qualification: (Ref = Post-secondary/Not degree)				**23**
Bachelors or above	22	(9.0)	*	77
Teacher has a maths specialisation	-17	(22.7)		95
Instructional clarity in mathematics lessons: (Ref = High)				**50**
Moderate clarity	-7	(3.8)	†	50
Disorderly behaviour during lessons: (Ref = Few/None)				**11**
Some lessons	-44	(7.5)	***	68
Most lessons	-61	(9.3)	***	20

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

Principal and school-level characteristics

Learners attending schools located in cities and suburbs significantly outperformed those from schools in small towns or villages (16 percent of learners) by an average of 20 points – significant at the 10 percent level – and those attending schools in remote rural settings (six percent of learners) by 39 points. There was also a small, significant association between mathematics achievement and the principal's qualifications: learners in schools where the principal had a post-graduate qualification scored an average of 25 additional points over those who were not.

The number of computers in a school is one example of school-level resource availability. Only a quarter (24%) of learners attended schools that had more than 20 computers and these learners scored, on average, 50 points higher in the TIMSS mathematics assessment than those with less access. Presence of a science laboratory is another example of the school-level resourcing reflecting access to resources which can create practical engagement with learning. In Gauteng, around two-thirds of all Grade 9 learners (65%) attended schools that had a science laboratory and scored, on average, 23 points more than those in less well-resourced schools.

The TIMSS 2019 instruments included a number of items and indicators of the overall school climate. At the bivariate level, all indicators about the overall school climate were significantly associated with learner achievement in mathematics. Learners in schools that placed a strong emphasis on academic success scored an average of 29 points more than those in schools where the emphasis was described as medium. Similarly, learners in schools where the promotion of academic excellence was reported to be high scored an average of 27 points more than those in schools where this was reported as medium, and 30 points more than where it was said to be low. In schools where principals reported hardly any problems with discipline, learners scored 74 points higher than those in schools where such behaviour was a minor problem and 106 points more where discipline levels were rated as moderately to severely problematic.

Learners in the safest and most orderly schools, as reported by teachers, scored, on average, 49 points more than those where safety was rated as moderate and 78 points higher than those in schools perceived to be less safe and orderly. In terms of learner reports regarding school safety, those who reported never or rarely being bullied scored, on average, 29 points higher than those who reported being bullied about monthly and an average 62 more than learners who experienced frequent, weekly bullying (See Chapter 7 for details).

Table 42: Basic associations between principal and school level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.	Percent
Spatial location of school: (Ref = Big and medium cities and suburbs)				**78**
Small towns or villages	-20	(11.5)	†	16
Remote rural	-39	(8.7)	***	6
Principal qualification: (Ref = Bachelor's or lower)				**82**
Post-Graduate qualification	25	(13.6)	†	18
Number of computers in the school: (Ref = Less than 20)				**76**
Over 20	50	(12.6)	***	24
School has a science laboratory	23	(8.8)	**	65
School's emphasis placed on academic success: (Ref = Medium)				**62**
High/Very high emphasis	29	(8.5)	***	38
School's promotion of academic excellence: (Ref = High)				**21**
Medium	-27	(11.4)	*	33
Low	-30	(10.9)	**	46
School discipline problems: (Ref = Hardly any)				**10**
Minor problems	-74	(14.5)	***	44
Moderate to severe problems	-106	(13.8)	***	46
Safe and orderly schools: (Ref = Very safe and orderly)				**19**
Safe and orderly	-49	(10.2)	***	52
Less than safe and orderly	-78	(10.1)	***	29
Learner is bullied: (Ref = Never/Almost never)				**39**
About monthly	-29	(3.0)	***	47
About weekly	-62	(4.8)	***	14

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

9.3. GROUPED MULTIVARIATE ASSOCIATIONS

The next step in our analyses is to understand how the factors affecting mathematics achievement operate jointly, within each broad category.

Household characteristics

The indicator of household SES, which takes into account the availability of certain resources in the home, continued to predict achievement when considered alongside the proxy measure of parental education (parents have difficulty understanding the homework LoLT and schoolwork is too difficult for parents). The size of these associations did fall slightly when taken together, particularly for the measure of schoolwork being too difficult for parents (the significant difference between never and sometimes falling away completely and becoming zero), indicating some degree of collinearity among the three household characteristics in the model. That is, while parents with higher SES are also more likely to have higher levels of education, each of the separate measures continued to significantly predict learner achievement in mathematics independently.

The strength of these relationships was greater for household SES and parental difficulties understanding the language of the test. Since parental understanding of the language of the test was more strongly associated with learner achievement in mathematics than their capacity to help with homework – likely because it better captures parents' own educational assets – we removed the complexity of schoolwork in the full multivariate model presented in section 4 of this chapter. We also collapsed together learners from middle and low SES households since they fared similarly poorly compared to those from high SES homes.

Table 43: Multivariate associations between characteristics of the household and achievement

Household Characteristics	Coeff.	SE	Sig.
Household SES indicator: (Ref = High)			
Middle	-50	(4.5)	***
Low	-60	(5.4)	***
Parents have difficulties understanding LoLT: (Ref = Never)			
Sometimes	-28	(2.6)	***
Always/Almost always	-45	(3.6)	***
Schoolwork is too difficult for parents: (Ref = Never/Almost never)			
Sometimes	0	(2.4)	
Always/Almost always	-18	(3.8)	***

Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10. R-squared given in Figure 55.

Individual-level characteristics

When learners' gender, age and language proficiency were considered jointly, in terms of their relationship with mathematics achievement, the most notable shift was the reversal of the gender gap: once age for grade and language proficiency were considered, the advantage favouring girls shifted to favour boys. This result reflects twofold selection effects operating in the TIMSS Grade 9 data: (i) a higher proportion of boys were overage for their grade[56]; and (ii) all else being equal, boys were more likely to be held back than girls. That is, lower achieving boys are held back and drop out completely while similarly low performing girls move through the system without interruption[57].

The coefficients for learner age did not substantively change in the individual-level grouped regression, i.e. overage learners still achieved significantly lower than those who were the correct age for the grade. The importance of proficiency in the test language and learner achievement fell slightly, but remained highly significant in the grouped model.

Table 44: Multivariate associations between individual-level characteristics and achievement

Individual-level Characteristics	Coeff.	SE	Sig.
Girl	-6	(2.4)	*
Age bands: (Ref: Correct age)			
Overage by up to 12 months	-47	(3.8)	***
Overage by more than 12 months	-73	(4.4)	***
Language proficiency: Speak language of test at home: (Ref = Always/Almost always)			
Sometimes	-48	(4.4)	***
Never	-53	(5.5)	***

Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10. R-squared given in Figure 55.

Learner attitudes to learning

Taken together, learners' educational attitudes showed an interesting relationship with achievement in mathematics: the association with learner confidence increased slightly, with those who were very confident in the subject scoring, on average, 76 points higher than those who were somewhat confident, and 108 points more than those who reported no confidence in their mathematical capabilities (up from 72 and 98 points in the bivariate models, respectively).

The relationship with 'liking' mathematics, however, reversed, with learners who reported not enjoying mathematics scoring 19 points higher than those who said they really liked it once their level of confidence in the subject was accounted for. This seemingly odd finding reflects both the high correlation between confidence and liking of mathematics (r = 0.62), as well as the lack of variation in achievement scores across the different levels of learner enjoyment. The average learner achievement in mathematics for those who reported strongly liking mathematics was 432 points (SE = 4.07), for moderate levels of enjoyment the average score was 415 (SE = 3.36) and for those who said they did not like mathematics at all, their average score was 417 (SE = 3.99).[58] The corresponding scores by levels of learner confidence were 501 (7.29), 430 (3.04) and 403 (3.02), respectively.

Given the small association between learners' valuation of mathematics and their achievement in the bivariate model above, we excluded this measure of learner educational attitudes from our analysis.

56 In the TIMSS 2019 data for Gauteng, 70% of boys were the correct age for grade 9 compared to 86% of girls. Of those who were overage, 19% of boys were overage by up to 12 months compared with 10% of girls; and 11% of boys were older by more than a year versus 4% of girls.

57 These results are presented and discussed in full in Hofmeyr (forthcoming HSRC working paper, 2022).

58 The difference in average scores between learners who reported moderate enjoyment of mathematics (415) and those who stated they did not like mathematics (417) was not significant.

Table 45: Grouped multivariate associations between learner educational attitudes and achievement

Learner Attitudes	Coeff.	SE	Sig.
Learner confident in mathematics: (Ref = Very confident)			
Somewhat confident	-76	(6.7)	***
Not confident	-108	(7.3)	***
Learner likes mathematics: (Ref = Very much likes)			
Somewhat likes	8	(3.4)	*
Does not like	19	(4.9)	***

Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10. R-squared given in Figure 55.

Educator and classroom characteristics

When all the educator and classroom characteristics were considered simultaneously, the majority of the bivariate relationships held. The association between the measures of educator qualifications and instructional clarity, and learner achievement, were no longer significant when all characteristics were considered jointly.

As with the other multivariate grouped regressions, with the inclusion of all variables, the strength of these associations fell, reflecting the collinearity (inter-relationships) between the different characteristics of the classroom context. The resulting coefficients and significance levels provide an indication of which influences are independently linked to – and thus more likely to have the largest impact on – achievement. For example, in the bivariate model learners in classes not affected by a shortage of mathematics resources scored, on average, 89 points more than those in classes that were affected. Once other indicators of classroom resources were considered – access to workbooks, textbooks and class size – alongside classroom climate, this relationship was reduced by around half, falling to a smaller 48-point advantage. This is still a large and significant difference, but better reflects the unique contribution of resource shortages specific to mathematics.

Similarly, when taken together and considered alongside other classroom and educator characteristics, the relationship between learner access to both workbooks and textbooks and their achievement roughly halved. Since the size of this association was similar for both resource indicators and access was correlated (r = 0.34), in the full model later, to present a more parsimonious picture, we only consider the relationship between sole access to a textbook and learner achievement.

Table 46: Multivariate associations between educator and classroom characteristics and achievement

Educator and Classroom Characteristics	Coeff.	SE	Sig.
Learner does not have own workbook	-18	(3.7)	***
Learner does not have own textbook	-17	(4.8)	***
Shortage of mathematics resources: (Ref = Instruction not affected)			
Affected/Affected a lot	-48	(12.5)	***
Instructional materials and supplies: (Ref = Not a problem/Minor problem)			
Moderate/Serious problem	-20	(7.1)	**
Class size: Over 37 learners	-34	(8.5)	***
Educator qualifications: (Ref = Post-secondary/Not Degree)			
Bachelors or above	8	(7.5)	
Instructional clarity in mathematics lessons: (Ref = High)			
Moderate clarity	-4	(3.1)	
Presence of disorderly behaviour during lessons: (Ref = Few/None)			
Some lessons	-27	(6.5)	***
Most lessons	-36	(8.2)	***

Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10. R-squared given in Figure 55.

Given that neither learner reports of the level of instructional clarity or educator qualifications significantly predicted achievement in mathematics, we removed these measures of the classroom in our full multivariate model that follows.

Principal and school-level characteristics

In the joint model of school-level characteristics, most relationships from the bivariate analysis remained significant despite being somewhat reduced in size: the number of computers in schools, school discipline problems, perceived safety and levels of bullying all had strong, independent and significant associations with mathematics achievement. The school climate measures here were particularly interesting as, while reduced, the level of discipline problems, overall school safety and the prevalence of bullying each continued to show a significant, independent relationship with learner achievement.

However, once considered jointly with other measures of the school context, and reflecting the collinearity between the indicators, the relationship between school location, principal qualifications, presence of a science laboratory and the emphasis placed on academic success within the school fell substantially, and no longer significantly predicted learner achievement.

Table 47: Multivariate associations between principal and school-level characteristics and achievement

Principal and School-level Characteristics	Coeff.	SE	Sig.
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages	-4	(10.0)	
Remote rural	-18	(17.8)	
Principal qualification: (Ref = Bachelor's or lower)			
Post-graduate qualification	16	(9.7)	
Number of computers in the school: (Ref = Less than 20)			
Over 20	21	(9.9)	*
School has a science laboratory	12	(7.5)	
School's emphasis placed on academic success: (Ref = Medium)			
High/Very high emphasis	-4	(7.9)	
School Discipline Problems: (Ref = Hardly any)			
Minor problems	-49	(17.6)	**
Moderate to severe problems	-72	(19.4)	***
Safe and orderly schools: (Ref = Very safe and orderly)			
Safe and orderly	-24	(10.6)	*
Less than safe and orderly	-38	(12.4)	**
Learner is bullied: (Ref = Never/Almost never)			
About monthly	-15	(2.6)	***
About weekly	-42	(4.3)	***

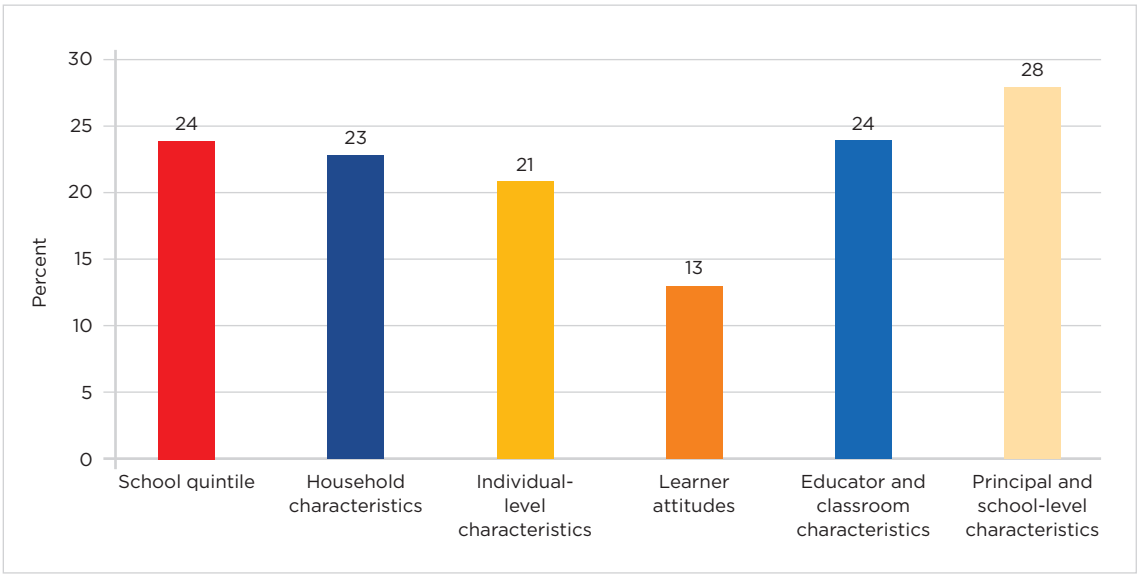
Source: Authors' own calculations from TIMSS 2019 South African (Gauteng) Grade 9 dataset.
Significance levels: *** p<.001; ** p<.01; * p<.05; †p<.10. R-squared given in Figure 55.

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

Each set of grouped regressions (Tables 43 to 47) were related to learner achievement in mathematics in different ways and to varying degrees. One way to compare the contributions of each set of associations (or covariates) on overall performance in the TIMSS assessment is to look at the proportion of variation in achievement that the individual, home and school-level factors are able to explain, that is the r-squared value.

Figure 55 shows how much of the variance in mathematics achievement each set of covariates was able to account for. In Gauteng, the quintile rank of each school was strongly and significantly associated with achievement, and alone accounts for around a quarter (24 percent) of the variation in Grade 9 learner performance for the province. The household SES and education indicators accounted for 23 percent of the variation in achievement, while the individual-level characteristics (gender, age and language proficiency) accounted for 21 percent of the achievement variation. The two measures of learners' educational attitudes were able to explain a smaller, but still sizeable, 13 percent of the variance. Educator and classroom characteristics accounted for the same proportion of overall variance as school quintile, that is 24 percent, but principal and school-level characteristics accounted for the highest proportion, at 28 percent.

Figure 55: The percentage of variance in TIMSS mathematics achievement accounted for by different blocks of covariates



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

In the same way that indicators within the different groups of covariates were related to each other, so too were the different blocks themselves: learners from higher quintile schools were more likely to come from higher SES homes where parents have higher educational qualifications and greater proficiency in the language of learning and teaching; smaller, more orderly classrooms were more likely to be found in safer schools where bullying is less prevalent. As such, the proportion of variance accounted for by each set of covariates cannot be thought of as additive, but rather an indication of the relative differences in the size of each contributing area. To understand the total variation in learner achievement explained by these factors, and identify the strongest predictors of mathematics performance, we need to consider how all these factors operate together in the day-to-day experience of Gauteng learners, that is jointly.

9.5. FULL MULTIVARIATE MODEL

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

Table 48 reports the coefficients – the size of each unique relationship with achievement – for a single regression model. The multivariate model used is deliberately simple, focusing on indicators shown in the preceding chapters (and earlier tables) that were significantly correlated with achievement, and tangible characteristics of the learners' environment that were most likely to be amenable to change. When all the variables were considered jointly, many of the associations remained significant.

Where previously significant associations became non-significant – for example, the presence of disorderly behaviour in classrooms – it indicates that their relationship with achievement had its effect through another factor, possibly school discipline problems or safety. That is, the association with achievement was mediated by something else. Where associations became significant in the full model (e.g. principal qualifications) it suggests that once other factors were taken into account (such as, school quintile) these indicators did, in fact, have independent relationships with learner achievement.

In the full model with all individual, household, educator and school characteristics considered jointly, learners in both Quintile 4 and 5 schools continued to score significantly higher than those in Quintile 1 schools, by an average of 21 and 39 points, respectively. Interestingly, the size of this association for Quintile 4 learners did not decrease when other variables were included, but was halved for those in Quintile 5 schools, suggesting that other variables in the full model mediated this relationship for learners in the most well-resourced, Quintile 5 schools.

Over and above the school quintile rank, household SES and parents' own proficiency in the LoLT (our proxy for parental education) continued to both have strong and significant associations with achievement, confirming the enduring impact of an individual's early circumstances in affecting subsequent achievement. While still highly significant, the size of these coefficients reduced considerably. For example, the average difference between learners from high SES households and those from low or middle SES homes fell from over 50 points to an average of 11 points, reflecting the strong interrelationship between school quintile ranking and family-level SES. The coefficients on parental language proficiency halved when considered alongside other factors: this proxy for parental education was also correlated with others in the model, but to a lesser extent than our indicator of household SES.

For the individual-level factors, when all other factors were considered, boys scored significantly higher than girls by an average of seven points. This result is in line with the findings of others (for example, Hofmeyr, forthcoming) who note selection effects in understanding gender differences in mathematics achievement.

On average, overage learners continued to do less well than those of the correct age, and language proficiency in the language of the test remained an important factor in explaining mathematics achievement. In both cases the size of the coefficients fell considerably.

Interestingly, both measures of learner attitudes (confidence and liking) towards mathematics continued to significantly predict learners' mathematics performance. Learners who reported liking mathematics very much achieved, on average, a significant 11 points higher than those who did not like mathematics. In the multivariate model, the relationship between the extent of learners' confidence in mathematics remained significant and strong.

Within classrooms, access to resources (both textbooks and mathematics-specific instructional resources) continued to predict learner achievement. However, class size and the presence of disorderly behaviour were no longer significantly related to achievement. Given that these relationships were previously observed as significantly related to performance in TIMSS mathematics (Tables 5 and 10), the lack of significance in the full model suggests that these associations were mediated through other factors related to achievement, such as school climate measures, including discipline problems and the prevalence of bullying.

In terms of the principal and broader school-level characteristics, there continued to be no significant differences in learner achievement based on the spatial location of schools. Interestingly, in the full model, learners in schools where principals were in possession of post-graduate qualifications scored significantly higher than those in schools with lower qualified heads of school. We also noted that once the resourcing of schools based on their quintile ranking, as well as specific classroom-level access was taken into account, the number of computers in schools no longer significantly predicted achievement in mathematics.

Most school climate measures continued to show strong, significant relationships with learner achievement, even when they were considered with other important learning contexts, despite some attenuation in the size of the associations. School discipline problems and higher levels of bullying each had independent associations with performance in mathematics, over and above school quintile rank, individual, family and other class and school-level factors.

Building on the R-squared figures reported in Figure 55, when considered jointly the full multivariate model was able to account for just over half (53%) of the variation in learners' mathematics achievement. This is a reasonable proportion of variance and indicates that our model – using just 18 variables across individual, family and school level contexts – captured the factors associated with achievement in mathematics well and was a reasonable 'fit' for the TIMSS 2019 Gauteng sample.[59]

Table 48: Multivariate associations between all factors and achievement

	Coeff.	SE	Sig.
School Quintile			
Quintile: (Ref = Q1)			
Q2	3	(7.8)	
Q3	1	(8.5)	
Q4	21	(8.5)	*
Q5	39	(9.0)	***
Household Characteristics			
Household SES indicator: (Ref = High)			
Middle/Low	-11	(2.9)	***
Parents have difficulties understanding LoLT: (Ref = Never)			
Sometimes	-12	(2.1)	***
Always/Almost always	-28	(2.5)	***
Individual-level Characteristics			
Girl	-7	(2.1)	**
Age bands: (Ref = Correct age)			
Overage by up to 12 months	-33	(3.3)	***
Overage by more than 12 months	-50	(4.3)	***
Language proficiency: Speak language of test at home: (Ref: Always/Almost always)			
Sometimes	-12	(2.7)	***
Never	-16	(4.3)	***
Learner Attitudes			
Learner confident in mathematics: (Ref = Very confident)			
Somewhat confident	-43	(3.9)	***
Not confident	-65	(4.0)	***
Learner likes mathematics: (Ref = Very much likes)			
Somewhat likes	-3	(3.1)	
Does not like	-11	(3.9)	**

59 The full multivariate model for the national data was able to account for 50 percent of the variation in achievement.

	Coeff.	SE	Sig.
Educator and Classroom Characteristics			
Learner does not have own textbook	-9	(3.7)	*
Shortage of mathematics resources: (Ref = Instruction not affected)			
Affected/Affected a lot	-21	(11.3)	†
Class size: Over 37 learners	-6	(5.9)	
Presence of disorderly behaviour during lessons: (Ref = Few/None)			
Some lessons	-5	(3.8)	
Most lessons	-7	(5.2)	
Principal and School-level Characteristics			
Spatial location of school: (Ref = Big and medium cities and suburbs)			
Small towns or villages and remote rural	4	(4.7)	
Principal qualification: (Ref = Bachelor's or lower)			
Post-graduate qualification	11	(5.2)	*
Number of computers in the school: (Ref = Less than 20)			
Over 20	10	(7.2)	
School discipline problems: (Ref = Hardly any)			
Minor problems	-25	(11.2)	*
Moderate to severe problems	-34	(12.3)	**
Safe and orderly schools: (Ref = Very safe and orderly)			
Safe and orderly	-4	(7.1)	
Less than safe and orderly	-10	(7.6)	
Learner is bullied: (Ref = Never/Almost never)			
About monthly	-5	(2.2)	*
About weekly	-17	(3.9)	***
R-squared	**0.53**		

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

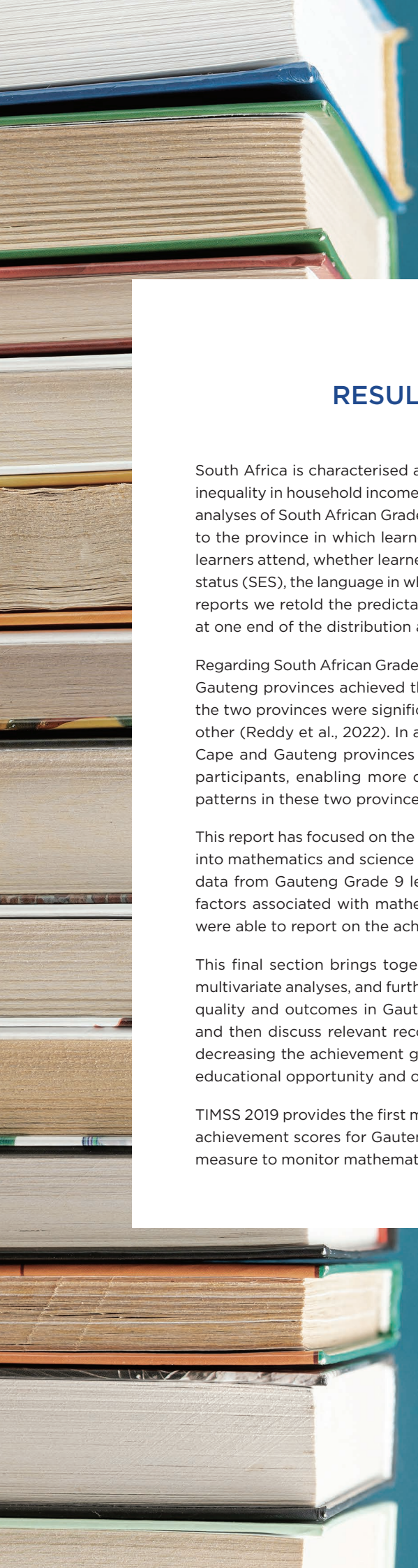
9.6. SUMMARY: FACTORS ASSOCIATED WITH MATHEMATICS ACHIEVEMENT

The preceding analysis is presented in a sequential manner, starting with basic associations as a gauge to the relative sizes of correlations between important characteristics of learners' lives and their achievement in mathematics, building up to a comprehensive, yet relatively parsimonious, model of the key factors affecting performance. Our aim was to highlight how certain relationships might change when multiple factors are considered together, demonstrating the importance of examining the influence of characteristics jointly, and identifying the biggest predictors of Grade 9 TIMSS mathematics performance.

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

- An individual's circumstances at birth remain critical determinants of life chances, including the schools that learners attend. While the home SES and the level of parental education contributes to the level of educational outcomes, schools do have the capacity to positively improve educational outcomes.
- In Gauteng, compared to the national picture, there appears to be less variation in achievement among Quintile 1 to 3 learners. Once family SES and other school-level factors were taken into account, only learners in fee-paying Quintile 4 and 5 schools (48 percent of learners in the province) outperformed those in Quintile 1 schools.
- Over and above the school's quintile status, school-level characteristics were particularly salient in predicting learner achievement, accounting for the highest proportion of variance in mathematics performance across any of the contexts considered.
- Schools need to be safe places for both learners and educators to attend. Unsafe classrooms, where bullying is frequent and discipline is a problem, disrupt the learning environment and hinder learners' achievement. These aspects of the school environment mattered independently of each other, and their impact is likely cumulative, compounding poor performance and limiting the opportunities of learners.
- Access to resources matters. Individual access to textbooks and workbooks were key predictors of achievement, and increasing these resources as well as others specific to the teaching of mathematics, are tangible examples of areas to prioritise.
- Overage learners, probably due to grade repetition, appear to be having limited educational success. Learners do not seem to be gaining the missed learning by repeating grades and continued to perform less well relative to those who were the correct age for the grade.
- Our bivariate analysis shows that girls significantly outperformed boys, but when age was considered, the advantage shift to boys. There are important selection effects operating within grade repetition and progression practices that need further investigation.
- This analysis confirms previous studies that found that learners who frequently spoke the language of instruction, were regularly exposed to it, and used the language outside of school, were at an advantage.
- Recognising that attitudes and achievement mutually reinforce each other, we observe that learners' own academic beliefs were key predictors of their achievement: being confident in and enjoying learning mathematics were associated with higher scores.

In the final part of this report, Section G, we present a set of key findings and implications for the Gauteng education system from the 2019 Grade 9 TIMSS assessment.



SECTION G
RESULTS AND IMPLICATIONS

South Africa is characterised as one of the most unequal countries in the world, with high inequality in household income and educational outcomes. As reported from previous TIMSS analyses of South African Grade 5 and Grade 9 data, achievement gaps are evident in relation to the province in which learners' schools are located, the quintile rank of the school that learners attend, whether learners live in an urban or rural area, their parents' socioeconomic status (SES), the language in which learners are most proficient, and learners' gender. In these reports we retold the predictable South African story of 'advantage begetting advantage' at one end of the distribution and compounding disadvantage at the other end.

Regarding South African Grade 9 learners' performance in TIMSS 2019, the Western Cape and Gauteng provinces achieved the highest scores. The mathematics and sciences scores for the two provinces were significantly different from all other provinces as well as from each other (Reddy et al., 2022). In addition to forming part of the national sample, the Western Cape and Gauteng provinces participated in TIMSS 2019 as self-standing benchmarking participants, enabling more detailed analysis and further insight into the achievement patterns in these two provinces.

This report has focused on the Gauteng provincial schooling system and provided an insight into mathematics and science achievement at the Senior Phase. We analysed self-reported data from Gauteng Grade 9 learners as well as their educators and principals to identify factors associated with mathematics and science achievement. Through this process we were able to report on the achievement gaps that exist within the province.

This final section brings together the main results from the descriptive, inferential, and multivariate analyses, and furthermore provides policy implications for improving education quality and outcomes in Gauteng province. We first highlight key results from the study, and then discuss relevant recommendations for improving educational achievement and decreasing the achievement gaps in Gauteng, i.e. steps towards addressing inequalities in educational opportunity and outcomes.

TIMSS 2019 provides the first methodologically sound measure of mathematics and science achievement scores for Gauteng in an international study. It can thus become the baseline measure to monitor mathematics and science progress at the Senior Phase in the province.

CHAPTER TEN

RESULTS, IMPLICATIONS AND RECOMMENDATIONS FROM THE GAUTENG PROVINCE TIMSS 2019

A. RESULTS FROM THE GAUTENG PROVINCE TIMSS 2019

GRADE 9 MATHEMATICS AND SCIENCE PERFORMANCE

1. **Achievement in TIMSS 2019:** Of the 39 countries and seven benchmarking entities that participated in TIMSS 2019 at the Senior Phase, the Gauteng province performance was in the lowest quarter of participants with an average mathematics scale score of 421 (3.0) and average science scale score of 422 (3.9).

   There was a high variation in both the mathematics and science scores. The achievement difference (achievement inequality) between the 5th and 95th percentiles was 253 points for mathematics and a higher 324 points for science. This suggests that science learners experienced additional difficulties in accessing the science content.

2. **Mathematics and science ability in TIMSS 2019:** In Gauteng, 58 percent of mathematics learners and 57 percent of science learners had acquired the basic subject knowledge for Grade 9 (i.e. scores above 400 points). It is noteworthy that six percent of mathematics and 11 percent of science learners reached the higher international achievement benchmarks, meaning that they were able to apply their understanding and knowledge in a variety of complex situations. Learners achieving scores above 400 points could potentially take mathematics as a subject in the FET phase.

3. **Achievement trends and improvement rates:** From 2011[60] to 2019, the average achievement in TIMSS within the Gauteng province significantly improved by 24 points in mathematics and 26 points in science.

   The average achievement improvement rate for the province from 2011 to 2019 was 3 points per year for mathematics and 3.3 points per year for science, both lower than the average achievement improvement rates for South Africa.

4. **Achievement and ability gaps by school poverty index or quintile rank:** The average mathematics and science achievement scores of learners in Quintile 1 to 3 schools were not significantly different from each other. Learners in Quintile 4 schools achieved significantly higher scores than those in Quintile 1 to 3 schools, but significantly lower than learners in Quintile 5 and independent schools. Learners in Quintile 5 and independent schools had similar average achievement scores.

   On average, close to 40 percent of learners in Quintile 1, 2 and 3 schools, 55 percent in Quintile 4 schools, and 80 percent in Quintile 5 and independent schools demonstrated that they had acquired basic mathematical and scientific knowledge and skills.

5. **Achievement and ability gaps by no-fee and fee-paying[61] schools:** In this socially graded and unequal education system, the average mathematics score for learners in no-fee schools was 385 (3.3) and in fee-paying schools it was 446 (4.5). This means that the mathematics achievement gap between learners in no-fee and fee-paying schools was 61 points.

   The average science score in no-fee schools was 375 (4.6) and in fee-paying schools it was 456 (5.6), with a science achievement gap of 81 points. This larger gap also suggests that science learners experienced additional difficulties in accessing the science content.

60 We cautiously comment on achievement trends as the smaller TIMSS 2011 Gauteng provincial sample size of around 30 schools led to high standard errors (SE).

61 Quintile 1, 2, and 3 schools were categorised as no-fee and Quintile 4 and 5 and independent schools were classified as fee-paying.

6. **Achievement and ability gaps by gender:** In Gauteng, there were fewer boys than girls in Grade 9, with a 10-percentage point difference between the two groups. The average age of girls was 0.5 years younger than boys and 86 percent of girls were at the correct age for the grade compared to 70 percent of boys. When all factors were taken together during the multivariate analysis, boys achieved significantly higher scores than girls, but these results must be interpreted in line with the selection effects of who stays in school.

7. **Achievement gaps by location of the schools:** Gauteng is a largely urban province with three quarters of learners living and learning in urban or suburban areas. The other learners live in small towns, villages or remote rural areas. Learners who attended schools in remote areas and small towns and villages experienced multiple disadvantages and they achieved significantly lower mathematics and science scores than learners in areas closer to bigger cities and towns.

HOME AND INDIVIDUAL, SCHOOL AND CLASSROOM CONTEXTS

Like other low-performing TIMSS participants, the Gauteng province responses from learners, educators and principals on their respective questionnaires were overly positive and optimistic on some items which did not always match the educational reality.

Home assets, socioeconomic status and individual characteristics

8. The availability of assets and educational resources in the home was significantly associated with mathematics and science achievement. Thirty-seven percent of learners came from homes categorised as high SES, 34 percent from medium SES homes, and 29 percent from low SES homes.

   There were differences in learners' home SES by the fee status of schools they attended: half the learners (46%) in no-fee schools, compared with 17 percent in fee-paying schools, came from homes characterised as low SES.

9. Half of the learners reported that their parents were not able to assist them with homework because they could not understand the language of the homework, and 42 percent reported that their parents could not understand the homework content.

10. Household characteristics (assets and parental education) explained 23 percent of the achievement variance. This finding confirms one of the enduring findings in the social science literature: the circumstance of one's birth and parental education predict much of one's educational and life trajectory.

11. Gauteng is a linguistically diverse province with representation of all 11 official languages in schools. isiZulu was the most common language spoken at home (22%) followed by Setswana (16%) and Sesotho (15%).

    Four in ten Gauteng Grade 9 learners (22% in no-fee schools and 51% in fee-paying schools) reported that they frequently spoke the language of the test (either English or Afrikaans) at home and therefore had better linguistic access to the TIMSS assessment.

    Learners who frequently spoke the language of the test at home achieved significantly higher scores than those who spoke the language of the test less frequently at home.

12. In Gauteng, 21 percent of Grade 9 learners (26% in no-fee schools and 17% 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 the grade achieved significantly higher mathematics and science scores than those who were overage.

13. Learner attitudes towards mathematics and science explained 13 percent of achievement variation. There was a significant association between learners' confidence in their mathematics and science abilities and their achievement, as well as between the extent to which they liked these subjects and achievement.

Schools and classrooms

14. There was a high variation in learning outcomes among different types of schools in the Gauteng province. The quintile rank of the school that a learner attended explained 24 percent of the achievement variance.

    Learners attending Quintile 1, 2, 3 and 4 schools were mostly Black African. The Quintile 5 cohort was made up 64 percent Black African learners. Almost all White and Indian/Asian learners attended Quintile 5 schools, making up 23 percent and four percent of this cohort, respectively.

15. Over 80 percent of learners attended schools where the reported educational qualifications of mathematics and science educators and 90 percent of the principals' qualification were at least a Bachelor qualification. Ninety percent of learners were taught by educators who reported a specialisation in mathematics or science.

    Achievement was not associated with the level of tertiary education reported by educators, nor the extent of professional development courses that educators had attended.

16. Compared with other TIMSS 2019 countries and benchmarking entities, the Gauteng province experienced higher levels of disciplinary, safety and bullying problems. Most learners attended schools that were characterised by unsafe conditions, ill-discipline in the school and classroom, and widespread learner bullying. Learners who were in safer schools with hardly any discipline problems in the school and classroom, and who hardly experienced any form of bullying, achieved significantly higher mathematics and science scores.

    There were significantly higher levels of ill-discipline, unsafe conditions, and incidences of bullying behaviours in no-fee schools than in fee-paying schools.

17. Learners who attended schools that placed a higher emphasis on academic success and who promoted academic excellence achieved significantly higher mathematics and science scores than learners in schools that placed less emphasis on academic success or excellence.

    There was significantly higher parental expectations and support for learner achievement and more learners respected academic excellence in fee-paying schools than in no-fee schools.

18. The average number of learners in Gauteng TIMSS Grade 9 classes was 41, with class sizes in Quintile 1 to 4 schools clustered around 45 learners, and an average of 36 learners in Quintile 5 schools and 29 learners in independent schools.

    Thirty-six percent of learners (14 percent in no-fee schools and 52 percent in fee-paying schools) attended classes with less than 37 learners. Learners in classes with fewer than 37 learners scored significantly higher average mathematics and science achievement than those in classes with more than 37 learners.

19. Overall, 88 percent of all mathematics learners and 80 percent of science learners had their own workbooks, while three-quarters of mathematics and science learners had their own textbooks. Learners in fee-paying schools had slightly higher access to mathematics and science textbooks and workbooks than learners in no-fee schools.

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

20. Two thirds of learners had no access to a computer while 18 percent had access to more than 20 computers in their Grade 9 classes. Learners in schools with more than 20 computers achieved higher mathematics scores than those with less than 20 computers for use by Grade 9 learners. While the Gauteng province has implemented plans to improve access to digital devices and introduce digital platforms for learning and instruction, the access to and usage in Grade 9 classrooms is very low.

CURRICULUM

21. TIMSS is not a simple assessment. Two-thirds of the Grade 9 items were classified as requiring learners to use the higher cognitive skills of application and reasoning to answer the TIMSS assessment successfully. However, the South African – and by extension Gauteng province – curriculum 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[62].

22. When compared to the Gauteng province average scores, mathematics learners performed significantly better in the algebra content area, while the content areas of geometry and data and probability proved more difficult for them. Performance in the physics content domain was significantly higher while the biology content domain was significantly lower than the provincial science average.

23. The average mathematics and science scale scores for knowledge items were significantly lower than the corresponding Gauteng mathematics and science mean scores. The science scale score for applying items was significantly higher and reasoning was significantly lower than the provincial mean score.

24. Learners performed better on items that required them to select a response (multiple choice questions) and had greater difficulty on items where they had to construct a written response. Learners struggled in writing coherent sentences and explanations or making an argument.

B. IMPLICATIONS AND RECOMMENDATIONS FROM THE GAUTENG PROVINCE TIMSS 2019 RESULTS

The main goal of TIMSS is to assist countries and benchmarking participants to evaluate their mathematics and science teaching and learning and monitor their achievement over time. The GDE's *Strategic Plan 2020–2025* (GDE, 2020) is a useful reference point to monitor and evaluate performance, as well as make recommendations for improving achievement outcomes in the province. What, then, do the TIMSS 2019 results tell us about the health of the Gauteng province Senior Phase education system?

The GDE strategic plan is informed by the South African *National Development Plan to 2030* (NPC, 2012), the Department of Planning, Monitoring and Evaluation's *Medium-Term Strategic Framework* (2019–2024) and the Department of Basic Education's (DBE) *Action Plan to 2024*. At the provincial level, it is informed by the Gauteng Provincial Government Plan *Growing Gauteng Together 2030* (Gauteng Provincial Government, RSA, 2020).

The GDE mission statement is to "provide functional and modern schools that enable quality teaching and learning to protect and promote the right of every learner to quality, equitable and relevant education." Of particular focus here is that Outcome 4 in the plan focuses on the promotion of quality education in the Senior Phase with the main emphasis on language, mathematics and science. Outcome 7 seeks to create a safer schooling environment that will embody social cohesion, patriotism and non-violence in schools.

Drawing on GDE's mission and priorities to achieve its goals over the next five years, we focus on four aspects from the Gauteng province TIMSS 2019 results to describe the implications and recommendations for improving achievement:

1. Monitoring and evaluating achievement and achievement gaps in the Gauteng province Senior Phase of the schooling system;

2. Improving school functionality and whole school improvement;

3. Making schools safer places of learning that emphasise academic excellence; and

4. Improving attitudes towards learning mathematics and science.

62 According to the CAPS documents, the mathematics assessment guidelines are: 25% knowing items, 45% routine procedures, 20% complex procedures and 10% problem-solving. For science: 40% lower order questions, 45% middle order questions and 15% higher order questions.

1. Monitoring and evaluating the Gauteng province's mathematics and science achievement and achievement gaps

The Gauteng province TIMSS 2019 average achievement scores fell within the lowest quarter of the TIMSS 2019 participating countries and entities. The province's mathematics achievement of 421 (3.0) was not significantly different from the performance of Jordan and Egypt, and its science achievement of 422 (3.9) was similar to the Emirate of Abu Dhabi (UAE).

There were no statistically significant differences in the average mathematics and science scores for learners in Quintile 1, 2, 3 schools. Average mathematics and science scores of learners in Quintile 4 were statistically different from all other quintiles, while the average achievement scores between Quintile 5 and independent schools were not statistically different.

The achievement inequality, the difference between achievement at the 5th and 95th percentile, for the Gauteng province was 253 points for mathematics and 324 points for science. The achievement gap between no-fee and fee-paying schools was 61 TIMSS points for mathematics and 81 points for science.

Learners from homes characterised as low SES achieved significantly lower scores than those from more affluent homes. There is a gender difference in achievement where boys significantly outperformed girls. Overaged learners and learners who did not speak the language of the test at home achieved lower scores.

Between 2011 and 2019, the Gauteng Grade 9 achievement scores increased significantly by 24 points for mathematics (average of 3 points per annum) and 26 points for science (average of 3.3 points per annum).

However, the conditions of the coronavirus pandemic and the implementation of social distance protocols led to losses of teaching and learning time, with projected decreases in achievement scores. Applying the methodology used by Soudien, Reddy and Harvey (2021) to estimate learning losses for South Africa to the Gauteng province, we estimated a loss of 3.8 percent of learning for 2021. The loss of learning time in schools in 2020 and 2021 will influence the TIMSS 2023 achievement scores.

One of the performance outcomes in the GDE *Strategic Plan 2020–2025* (GDE, 2020) (Indicator OCI-04, p. 56) is the percentage of learners completing the Senior Phase with a TIMSS mathematics score above the midpoint (the TIMSS centrepoint score is 500). The target is that 25 percent of learners will score above 500 points by 2025. In TIMSS 2019, 15 percent of mathematics learners and 22 percent of science learners scored above this centrepoint score.

The continued participation of the Gauteng province in TIMSS is important to measure achievement and monitor achievement gaps.

2. Improving school functionality and promoting whole school improvement

Parents and society expect the state and schools to reduce the inequality of opportunity gradient that characterises South African (and Gauteng) society. There is a large achievement variation between no-fee and fee-paying schools as well as within fee-paying schools. In general, learners are differentiated by their home SES and go on to enter schools that are differentiated by their resource base and learning and teaching cultures. The continuity from home to schools results in advantage begetting advantage and the continued reproduction of society for many learners.

For more learners to succeed in schools, the GDE needs to increase the number of well-functioning schools. Our findings corroborate the GDE strategic priority for whole school development and to improve functionality (GDE, 2020, p. 45). Schools and classrooms do have the capacity to positively improve educational outcomes. The results of this report show that, in Gauteng, the educator and classroom factors explained 24 percent of the achievement variance while the principal and school factors explained 28 percent of the variance. There are thus leverage points within schools that can contribute to improved learner outcomes.

One aspect of a well-functioning school is the class size. According to the Personnel Administrative Measures (DBE, 2016), the ideal maximum Grade 9 class size is 37 learners. However, only 36 percent of learners (14 percent in no-fee schools and 52 percent in fee-paying schools) attended classes with less than 37 learners. Learners attending classes with less than 37 learners achieved significantly higher scores than those in classes with more than 37 learners. The first step in achieving lower class sizes is an audit of how educators are utilised in school and how lessons are scheduled.

Access to resources is important for improved educational outcomes. Individual access to textbooks and workbooks were key predictors of achievement and increasing these resources, as well as others specific to the teaching of mathematics and science, are tangible examples of areas to prioritise. While the Gauteng province has implemented plans to improve access to digital devices and introduce digital platforms for learning and instruction, the access and usage in Grade 9 classrooms is very low. Two-thirds of Grade 9 learners had no access to computers in their classes.

3. Schools must be safer places of learning that emphasise academic excellence

In-school learning can only be facilitated and augmented if home and community environments are conducive to educational development. For example, if learners are coming from homes that have basic assets and resources and are situated in communities that are safe and free of crime.

Well-performing schools have a positive school climate that (i) emphasises and promotes academic success and (ii) provides a safe and orderly space for both learners and educators. Success in terms of these characteristics is determined by what the school does as well as how it involves learners, parents and the community.

As we noted in Point 16 earlier (under 'Schools and classrooms'), compared to other TIMSS participants, the Gauteng schools experienced higher levels of safety problems, ill-discipline in schools, disruptive behaviour in classrooms and incidences of bullying. Similarly, there was less emphasis on academic success compared to most TIMSS participants. There were also significant differences in how learners in no-fee and fee-paying schools in the province experienced school climate. Fee-paying schools fared better on characteristics of safe and orderly schools, behaviours related to discipline and bullying in school, as well as parental expectation and support for learner achievement.

School climate reflects the climate in communities surrounding the schools. Improving academic success will therefore involve a partnership between the school, parents and the community. The *Gauteng Provincial Strategic Plan* (2019–2024) (Gauteng Provincial Government, RSA, 2020), and the *GDE Strategic Plan* (GDE, 2020) are cognisant of the safety issues and there is a GDE School Safety and Security Policy encompassing all measures to be taken to combat threats to learners, teachers and school staff, including school property.

In implementing measures to improve school safety, one of the GDE's performance indicators is to measure "the number of high risk schools implementing a safe schools programme" (Indicator OCI-07). Ensuring safe schools will involve an intergovernmental programme, including strengthening its ties with the Department of Community Safety and other community-based organisations. Given the severity of the problem and its impact on learners' achievement, we recommend that a further performance indicator of safety be included: 'the number of schools that have regular community fora and parent engagements related to school safety and learning'.

4. Improving learners' attitudes to learning mathematics and science

We found that learner attitudes explained 13 percent of the achievement variation in the TIMSS 2019 results. Learners who liked learning mathematics and science and were confident in their abilities in these subjects (i.e. a realistic reflection of their abilities), achieved higher scores.

Learner confidence is part of a virtuous cycle that should be fostered and developed: doing well in mathematics and science improves feelings about, and one's capability in, these subjects. The honest reflection of one's capabilities is recognition of what needs to be done to improve achievement.

Therefore, we recommend interventions to improve learners' attitudes to learning mathematics and science and, in particular, for learners to become more confident in their abilities (reflecting realistically) and enhance their learning efforts. An intervention is that the GDE periodically administers short, validated instruments to obtain a profile of learners' attitudes and motivation. The results from this tool could provide the basis of a conversation between schools and their learners to improve their attitudes and behaviours towards learning.

CONCLUSION

In this report we have shown that while Gauteng was the second highest performing South African province in TIMSS 2019, there were high levels of educational inequality. The Gauteng province average mathematics and science achievement were found to be unequal and socially graded with achievement gaps linked to learners' socioeconomic backgrounds, gender, linguistic access, and the quintile rank of the school they attended. However, we also showed that there are some factors within the ambit of the school that can be changed.

To improve education levels in Gauteng province, there must be intentional and carefully targeted programmes for Quintile 1, 2, and 3 schools, as well as programmes to improve achievement scores in the better resourced schools. Raising the educational outcomes of these two groups of learners will contribute to raising the overall provincial achievement levels. These interventions are even more important in the wake of the coronavirus pandemic that has dealt the system a major blow – especially for the most vulnerable groups.

An unexpected learning from the analysis of the GDE system was that only 37 percent of Grade 12 learners sat for the mathematics matriculation examination compared with 63 percent for the mathematical literacy subject. This is perplexing and concerning, as close to 60 percent of Grade 9 learners achieved scores above 400 points, signalling they had acquired basic mathematical and scientific competences. These learners would more than likely succeed if they chose mathematics in the Further Education and Training (FET) phases. It is important to investigate why learners are not choosing mathematics in the FET phase, even when they have demonstrated sufficient mathematical abilities.

As is the case with nearly all research investigating influences on learner achievement, there is no one 'silver bullet' that will fix low performance, remediate years of social imbalance throughout the system, and penetrate the indelible association between one's circumstances at birth and economic and social outcomes; but these results, like those of previous TIMSS studies, highlight that there are many areas that can and must be improved.

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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 Gauteng 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:

- Pre-administration: Translating and preparing assessment instruments and contacting schools;
- Field testing on instruments;
- Main administration of the TIMSS 2019 assessments;
- Scoring of constructed responses; and
- Creating the TIMSS 2019 data files.

TRANSLATING AND PREPARING ASSESSMENT INSTRUMENTS

The HSRC adapted (for example by changing names and terminology like 'gas' to 'petrol') the assessment instruments for South Africa, and thus Gauteng, as well as translated them from English to Afrikaans in preparation for the 2019 assessment administration. These adaptations and translations were documented using the National Adaptations Forms which are verified by the International Association for the Evaluation of Educational Achievement (IEA) to assess if the national adaptations are likely to impact the ability to produce internationally comparable data. Once verification was complete, the HSRC assembled the achievement booklets and contextual questionnaires using Adobe® InDesign® software, and print-ready copies of the instruments were sent to the TIMSS and PIRLS International Study Center for layout verification and a final review of the national adaptations.

FIELD TESTING OF INSTRUMENT

In July 2018, the TIMSS test administration was piloted at four schools: two in KwaZulu-Natal and two in Gauteng. Approximately 500 learners participated in the field test which served as a dress rehearsal for the main survey. Through the field test and the data gathered from the various instruments the research team was able to:

- Determine how well items worked;
- Measure the validity and reliability of the various questionnaire scales/indices; and
- Develop a risk mitigation plan for any problems that may occur.

Contacting schools

Pre-administration contact with schools was extremely crucial and allowed the HSRC to:

- Obtain permission from the principal to conduct the study;
- Obtain class information (to randomly select a class during sampling);
- Obtain class lists with learner information; and
- Arrange appointments with the schools to administer the study.

The Gauteng provincial coordinator assisted the HSRC to obtain school and class information. The gathered information was entered into the Within-school Sampling Software (WinW3S) which was used to sample classes.

MAIN ADMINISTRATION OF TIMSS 2019

Consistency across countries is key and the international TIMSS team thus developed a test administrator manual, as well as two basic procedures to guide countries through the data collection phase.

Test administrator manual

The Test Administrator Manual detailed the procedures which had to be followed when administering the achievement booklets and Learner, School and Educator Questionnaire. This was a comprehensive document that provides details about preparing for each assessment, completion of the Student Tracking Form and the Test Administration Form, the timing of the testing sessions, correct procedure, and how to administer the assessment. The latter included the instructions to learners as a script that was to be read-out by the test administrator.

Administration of the main assessment

The main survey was administered by an external data collection company with relevant qualifications and experience in the field of data collection. The survey was administered in schools in August 2019. The HSRC worked closely with the Gauteng Department of Education (GDE) official and provincial coordinator to ensure that the study was successfully administered.

Monitoring the quality of the survey administration

Quality assurance of the fieldwork allows for valid learner achievement comparisons between and within countries. Thus, 10 percent of the sampled schools were randomly selected and senior HSRC researchers served as National Quality Control Monitors (NQCM) to observe the TIMSS administration process. The NQCM followed the National Quality Control Monitor Manual and completed a Classroom Observation Record for each school. This form was organised into the following four sections:

- Documentation of the TIMSS testing session;
- Summary observations of the TIMSS testing session;
- Learner Questionnaire administration; and
- Interview with the Test Administrator.

In addition, the international TIMSS team selected and trained an International Quality Control Monitor who monitored the administration process in 15 Gauteng schools. This process was independent of the HSRC.

Scoring the constructed response items

TIMSS assessment items comprised multiple-choice and constructed response (open-ended) items. The constructed-response items were scored by hand and hence the reliability and validity of scoring was critical to the quality of the assessment results. In order to achieve this, the IEA provided training, comprehensive scoring guides, and scoring procedures to country participants. The HSRC employed and trained educators and university students to conduct the scoring. As a quality control measure, eight percent of the learner achievement booklets were marked twice by independent scorers to provide a measure of consistency. This is referred to as reliability scoring.

Qualified and experienced moderators were responsible for moderating 25 percent of the scored achievement booklets on an ongoing basis for maintaining accurate and consistent scoring throughout the process. The HSRC staff supervised the scoring and moderation activities, and ensured that moderation and scoring proceeded as planned, information was recorded properly, and all procedures understood.

All TIMSS 2019 countries and benchmarking entities participated in the Cross-country Scoring Reliability Study (CCSRS). The actual scoring for CCSRS was conducted via an online scoring system. 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 Gauteng survey into data files with a common IEA format. This format used an international predefined codebook which was adapted by the national centre data managers to reflect the previously approved adaptions made to the background questionnaires. The data entry software used was Data Management Expert (DME). The following data files were used during data entry:

- Learner Background Data File;
- Learner Achievement Data File;
- Educator Questionnaire Data File with separated files for mathematics and science educators; and
- School Data File.

A data capturing error rate of one percent was acceptable for all contextual data and 0.1 percent for assessment data. As with all previous TIMSS cycles, the HSRC submitted data to the IEA with a zero percent error rate. In order to achieve these standards, data were double-captured and stringent procedures were followed during data processing.

Data processing

Data processing occurred in three phases. The first phase was performed by using the DME software which included four steps as follows:

- Unique ID check – Check for and list duplicate IDs in the datasets;
- Validation check – Check for all wild codes and out-of-range values;
- Double punching check – Compare data for agreement between first and second capture; and
- Record consistency check – Check inconsistent records across datasets.

The second phase involved updating the WinW3S database with information obtained from the test administration and learner tracking forms as received from data collection.

In the third phase, the DME and WinW3S databases were merged to address the next level of data anomalies. Once these phases were completed, data were exported for submission to the IEA for the final phase of data processing.

The IEA remained in constant contact with the country Data Managers at the HSRC once the final stage of cleaning had commenced. This was to ensure that any additional data-related queries from the IEA-DPC were solved by the HSRC in a timely fashion once physical instruments had been checked.

ANNEXURE 2: MATHEMATICS AND SCIENCE CURRICULA

Table 49: Overview of the mathematics curriculum in the Intermediate (Grades 4 to 6) and Senior (Grades 7 to 9) Phases

Content area	Intermediate Phase Grades 4 to 6	Senior Phase Grades 7 to 9
Numbers, operations, and relationships	• 9-digit whole numbers • Decimal fractions to two decimal places • Common fractions and fractions written in percentage form	• Representation of numbers in a variety of ways and moving flexibly between representations • Recognising and using properties of operations with different number systems; solving a variety of problems, using an increased range of numbers and the ability to perform multiple operations correctly and fluently
Patterns, functions, and algebra	• Numeric and geometric patterns with a special focus on the relationships between terms in a sequence between the number of the term (its place in the sequence) and the term itself	• Investigation of numerical and geometric patterns to establish the relationship between variables • Analysis of situations in a variety of contexts; representation and description of situations in algebraic language, formulas, expressions, equations, and graphs
Space and shape (geometry)	• Classification and more detailed description of characteristics and properties of two-dimensional shapes and three-dimensional objects	• Drawing and constructing a range of geometric figures and solids • Descriptions and classification of geometric figures and solids • Solving a variety of geometric problems drawing on known properties of geometric figures and solids
Measurement	• Enable learners to formally and informally measure angles, area, perimeter, and capacity/volume; discuss and describe the historical development of measuring instruments and tools	• Using formulas for measuring area, perimeter, surface area, and volume of geometric figures and solids • Selecting and converting between appropriate units of measurement • Using the Pythagorean theorem to solve problems involving right-angled triangles
Data handling	• Reporting on data • Critical analysis of data • Probability (perform repeated events to list, count, and predict outcomes)	• Collecting, summarising, representing, and analysing data to interpret, report, and make predictions • Probability of outcomes including both single and compound events

Table 50: Overview of the science curriculum in the Intermediate (Grade 4 to 6) and Senior (Grades 7 to 9) Phases

Content area	Intermediate Phase Grades 4 to 6	Senior Phase Grades 7 to 9
Life and living	• Living and nonliving things	• The biosphere • Variation within a species; photosynthesis and respiration; interactions and interdependence within the environment • Systems in the human body
Matter and materials	• Materials • Metals and nonmetals • Solids, liquids, and gases • The water cycle • Mixtures • Dissolving	• Properties of materials and impact on the environment • Separating mixtures • Acids and bases • Periodic table of elements • Compounds • Atoms • Change of state • Density, mass, and volume • Chemical reactions; reaction of metals with oxygen • Reactions of nonmetals with oxygen
Energy and change	• Energy and energy transfer • Sound • Electric circuits	• Energy • Potential and kinetic energy; law of conservation of energy • Series and parallel circuits • Visible light • Forces
Planet Earth and beyond	• Objects in the solar system • Planet Earth • Movement of the moon	• The Solar System • The Earth • Beyond the Solar System, including the Milky Way and the history and development of astrology

ANNEXURE 3: NON-COGNITIVE FACTORS IN THE CAPS DOCUMENTS

The South African Curriculum and Assessment Policy Statements (CAPS) relating to non-cognitive outcomes for mathematics and science.

- Confidence and competence to deal with any mathematical situation without being hindered by a fear of mathematics (p.8);
- An appreciation for the beauty and elegance of mathematics (p. 8);
- A spirit of curiosity and a love for mathematics (p. 8);
- Recognition that mathematics is a creative part of human activity (p. 8); and
- Learners can gain (science) skills in an environment that taps into their curiosity about the world, and that supports creativity, responsibility and growing confidence (p. 10).

The Gauteng TIMSS 2019 Grade 9 Results: Building Achievement and Bridging Achievement Gaps

The Grade 9 Trends in International Mathematics and Science Study (TIMSS) was administered in August 2019 by the Human Sciences Research Council, in collaboration with the Gauteng Department of Education, the Department of Basic Education and the International Association for the Evaluation of Educational Achievement. TIMSS 2019 collected learner achievement data in the core subjects of mathematics and science, as well as contextual information from learners, educators and school principals which enabled the exploration of factors that are associated with Grade 9 learners' achievement.

South Africa has participated in TIMSS at Grade 8 or 9 since 1995 with the assessment taking place every four years. In TIMSS 2019, the Gauteng province increased its sample size from 30 to 150 schools and participated as a self-standing benchmarking participant, while still forming part of the national sample. This larger sample size allows a more precise measure of provincial mathematics and science achievement scores as well as an opportunity to understand the texture of Gauteng achievement. Further, this larger sample allows for analysis to identify factors that are associated with Gauteng mathematics and science achievement.

This report highlights how the results of international assessments can be used to provide meaningful insights at the provincial level. We analysed the data from a 'building achievement and bridging achievement gaps' perspective. The findings presented in the report are based on descriptive and inferential analysis of the TIMSS data, and provide insights into learner achievement, as well as aspects of learners' home environments, and the school and classroom contexts within which teaching and learning take place. The report concludes with key findings and implications for the senior phase of the Gauteng education system.

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