MATHEMATICS AND SCIENCE ACHIEVEMENT AT SOUTH AFRICAN SCHOOLS IN TIMSS 2003

Vijay Reddy with contributions from Anil Kanjee, Gerda Diedericks and Lolita Winnaar

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Research Director, HSRC and TIMSS 2003 National Research Co-ordinator

EXECUTIVE SUMMARY

In November 2002, about 9 000 Grade 8 learners from South African public schools participated in the Trends in International Mathematics and Science Study (TIMSS). South Africa was one of 50 countries (and educational systems) that participated in this study. TIMSS is a project of the International Association for the Evaluation of International Achievement (IEA), an organisation that has been conducting cross-national studies since 1959. The Human Sciences Research Council (HSRC) has co-ordinated and managed the South African part of the study. TIMSS 2003 is the third TIMSS that South Africa has participated in – the others being in 1995 and 1999.

This analytical-descriptive report provides information, gained during TIMSS 2003, about South Africa's performance in mathematics and science at Grade 8 level. The report will first provide information regarding South Africa's performance in relation to the other countries that participated in the study, and cross-national comparisons will highlight South Africa's performance in relation to the other participating African countries. The report will then provide information on performance in mathematics and science within South Africa. The national analysis will also track changes over time. This national analysis is important to inform policy and planning within the country. In addition to achievement data, this report will include contextual information relating to learners, teachers and schools.

Research design

TIMSS is a large-scale comparative study and is conducted internationally at the end of the Grade 4 and Grade 8 year. South Africa participated in the Grade 8 study. TIMSS primarily measures learner achievement in mathematics and science, as well as learner beliefs and attitudes towards these subjects. The study also investigates curricular intentions and school and classroom environments.

TIMSS uses the curriculum, broadly defined, as the organising principle in how educational opportunities are provided to learners. The curriculum model has three aspects: the *intended curriculum*, the *implemented curriculum* and the *attained curriculum*.

TIMSS then developed items for the mathematics and science achievement tests. To accommodate the large number of items required in the limited testing time available, TIMSS used a matrix-sampling technique. This technique involved dividing the item pool among a set of 12 learner booklets. TIMSS collected information from curriculum specialists, learners in participating schools, their mathematics and science teachers, and their school principals.

TIMSS is a population survey and the sample of learners is representative of the population from which it is drawn – in South Africa these are the Grade 8 learners. For South Africa, the School Register of Needs (SRN) database was used to select the sample of schools. The sample was explicitly stratified by two dimensions:

- By province; and
- By the language of teaching and learning (English and Afrikaans were the languages of instruction chosen by schools).

The TIMSS sampling design used a three-stage stratified cluster design, which involved:

- Selecting a sample of schools from all eligible schools;
- Randomly selecting a mathematics and science class from each sampled school; and

- Sampling learners within a sampled class in cases where the number of learners in a class was greater than 40.

The testing for TIMSS 2003 took place in South Africa in November 2002, with 255 schools and 8 952 learners participating. The number of schools was over-sampled so that provincial calculations could be made.

What is assessed?

TIMSS assesses in the areas of mathematics and science and was framed by two organising dimensions: a content domain and a cognitive domain. The content domain defined the specific mathematics and science subject matter covered by the assessment and the cognitive domain defined the set of behaviours expected of learners as they engage with mathematics or science.

The content domains that framed the mathematics curriculum were: number, algebra, measurement, geometry and data. The cognitive domains for mathematics were: knowing facts and procedures, using concepts, solving routine problems, and reasoning. The content domains that framed the science curriculum were: life sciences, chemistry, physics, earth science, and environmental science. The cognitive domains were: factual knowledge, conceptual knowledge, and reasoning and analysis.

How are results reported?

TIMSS mathematics and science achievement scores were reported using average scale scores. The TIMSS scale average over the countries was set at 500 and the standard deviation at 100.

South Africa's performance in mathematics and science in TIMSS 2003

1. South African mathematics and science achievement in an international context.
   - The top performing countries for mathematics were Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei and Japan. The lowest performing countries were Lebanon, the Philippines, Botswana, Saudi Arabia, Ghana and South Africa.
   - The top performing countries for science were Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei, Japan and Estonia. The lowest performing countries were the Philippines, Botswana, Saudi Arabia, Ghana and South Africa.
   - South Africa had the lowest performance in mathematics and science of the 50 TIMSS participants.
   - The international average scale score for mathematics was 467 (Standard Error [SE] = 0.5) and the South African score was 264 (SE = 5.5).
   - The international average scale score for science was 474 (0.6) and the South African score was 244 (SE 6.7).
   - South Africa had the largest variation in scores, ranging from mostly very low, to a few very high scores, meaning this score distribution was skewed to the left.
   - South African performance in mathematics and science at international benchmarks is disappointing, with around 10 per cent in mathematics and 13 per cent in science achieving scores higher than 400 points (that is, higher than the Low International Benchmark). This means that, with Ghana, South Africa has the highest percentage of learners achieving a score of less than 400 points (that is, below the Low International Benchmark).

2. Gender analysis

- In most countries, including South Africa, there were equitable participation rates in mathematics and science classes with participation of girls and boys varying from 48 to 52 per cent. This was also the pattern in all the provinces in South Africa, except Eastern Cape and Gauteng where about 8 per cent more girls than boys participated.
- The international mathematics average scale score for girls and boys was not significantly different.
- There are 27 countries, including South Africa, where the mathematics average scores were not statistically different for boys and girls; in nine countries the girls score was statistically higher than the boys score; and in nine countries the boys score was higher than the girls.
- Internationally, the science average scale score for boys was statistically higher than for girls by six points.
- There are 11 countries, including South Africa, where the science average scores were not statistically different for boys and girls; in seven countries the girls score was statistically higher than the boys score; and in 28 countries the boys score was higher than the girls.

3. Participation patterns at Grade 8 level

- The average age of South African learners in TIMSS 2003 (administered in November 2002) was 15.1 years. This is 0.4 years lower than the average age of 15.5 years of TIMSS 1999 (administered in 1998).
- This drop in the average age, from 1998 to 2002, implies that there is either less repetition in the system or fewer learners leave the system and then re-enter.

4. Performance patterns at Grade 8 level

4.1. By province

- The average achievement scores in mathematics and science of the provinces showed great variation.
- The top performing provinces for mathematics and science were Western Cape and Northern Cape and the lowest performing provinces were Eastern Cape and Limpopo.
- The top performing provinces have scores which were almost double that of the lowest performing provinces.
- The socio-economic conditions in the provinces were/are different, with the top performers having a higher Human Development Index (HDI) rating than the poorer performing provinces.
- Although there are differences in the provincial average mathematics and science achievement scores for boys and girls, this difference is not statistically significant.

4.2. By schools categorised by ex-racial department

- There were differences in the average achievement mathematics and science scores of learners in schools categorised by ex-racial departments.
- Learners who were in ex-House of Assembly (HoA) schools – previously only for white learners – achieved an average mathematics and science score that was close to the international average.
- The average scores of learners in African schools was almost half that of learners in ex-HoA schools.

- There has been a migration of better performing and financially resourced African learners to more affluent ex-HoA schools. This means that African schools have to contend with both the disadvantages of apartheid as well as the migration of better performing learners – leaving these schools in difficult conditions when attempting to produce good results.
- The achievement scores in the different school types (categorised by ex-racial department) indicated that attendance of learners at different school types was an important determinant in influencing learner achievement outcomes.
- The difference between achievement scores of boys and girls in TIMSS 2003, in schools categorised by ex-racial department, was not statistically significant.
- In TIMSS 1999, the mathematics and science scores of girls in the ex-African schools were statistically lower than the scores of boys. While it is a positive sign that there was no noticeable gender difference in the scores of boys and girls in TIMSS 2003, the concern remains that both groups still score poorly.

4.3. By language of the test

- Learners answered the test in either Afrikaans or English.
- Those learners who took the test in Afrikaans achieved an average mathematics score and science score which was higher than those who took the test in English.
- Learners taking the test in Afrikaans were first-language users and their score would place this group just above the average score for Botswana on the international table.
- Most learners taking the test in English would be attending African schools and English would not be their first language.
- While the language of the test and learners' proficiency in that language contributed to the achievement scores attained, it is difficult to determine the extent of this contribution as there are other inequalities among the different school types which also influenced performance.

4.4. By what learners know and can do

- South African learners performed poorly on almost all test items.
- In most of the multiple-choice items, less than 30 per cent of the learners achieved the correct answer.
- The average percent correct on all mathematics and science items was just below 20 per cent.
- In mathematics, South African learners performed relatively well in the domains of measurement and data; while scoring the lowest in geometry.
- In science, they performed better in the chemistry domain; while their performance was weakest in the physics and earth science domains.

5. Trends in mathematics and science achievement

- The national achievement scores for mathematics and science was not, statistically, significantly different between TIMSS 1999 and TIMSS 2003. During this period there had been curriculum restructuring in the country.
- There were no statistically significant changes in the provincial mathematics scores in these two periods.
- In science, the increase in scores from TIMSS 1999 to TIMSS 2003 for Northern Cape and Limpopo is statistically significant.
- The mathematics score for African schools decreased 'significantly' from TIMSS 1999 to TIMSS 2003, and in ex-House of Representatives (HoR) schools the decrease in mathematics and science scores was 'not quite' statistically significant.

6. Performance at Grade 9 level

- The South African testing included an assessment of Grade 9 learners. Since South Africa has a band qualification, it was considered desirable to determine whether the sequence of topics taught would influence achievement scores.
- The Grade 9 performance in mathematics and science mirrors the Grade 8 performance.
- A disappointing feature of the results was that the average score for Grade 9 learners was only around 20 points higher than for Grade 8 learners.

7. Curriculum

- The TIMSS instruments were administered during a period of curriculum change and restructuring.
- During this period, teachers consulted different curricula to determine what and how they taught in their classrooms – NATED 550, C2005 and the Revised National Curriculum Statements.
- The philosophy underpinning the restructured curriculum was that of an outcomes-based education.
- The official curriculum in 2002 was C2005, and this was characterised by an under-specification of basic knowledge and skills in all learning areas, including mathematics and science.
- South Africa was one of the countries where there was the least overlap with the TIMSS assessment frameworks. While this may have had an effect on achievement scores, the analysis of performance on topics which teachers said had been covered indicated that performance was still very poor, with learners achieving only around 20 per cent correct on those items.

8. Learners

8.1. Home background

- Home background provides an insight into learners' social and economic capital. Therefore, TIMSS obtained information on parental education, the number of books at home, and how often the language of the test was spoken at home.
- About one-tenth of South African learners had parents who completed university or an equivalent education and around 30 per cent of learners had parents who had no more than a primary education.
- About one-tenth of learners indicated that they had more than 100 books in the home and about 40 per cent (one of the highest percentages in this category of the international dataset) had less than ten books in the home.
- Eighteen per cent of South African learners indicated that they 'always' spoke the language of the test at home, while 15 per cent indicated that they 'never' spoke the language of the test at home.
- The parental level of education, educational home resources, and use of the test language at home – and the effect these factors have on mathematics and science performance – all indicated that learners within a country who had these resources performed better than those who did not.
- Comparisons across countries indicated that even when these resources (high parental education and number of books, and speaking the language of the test at home) are in place, the South African average TIMSS mathematics and science scores were lower than other countries.

- None of these factors on its own can explain performance – to do this, it is the interaction of many factors, embedded within a context, which must be examined; only then is it possible to offer hypotheses of why performance may be high or low.

8.2. Attitudes

- Creating a positive attitude in learners towards mathematics and science is an important goal of the curriculum.
- In general, the attitude of South African learners to mathematics and science is positive – they have high self-confidence; they enjoy and value mathematics and science.
- In reading these responses, one must consider that the responses could be socially desirable answers and it would be necessary to probe further to determine the 'real' attitudes of learners.
- Internationally, and in South Africa, there were no significant variations in achievement scores between learners who indicated high positive attitudes to mathematics and science and those who did not.

9. Science and mathematics teachers

9.1. Profile of the teachers

- The teacher is central in creating an environment that supports learning of science and mathematics.
- The majority of mathematics and science teachers were aged between 30–39. The average teaching experience of mathematics teachers was 11 years and for science teachers it was ten years.
- In South Africa, about 40 per cent of mathematics learners and 50 per cent of science learners were taught by female teachers.
- Over 95 per cent of the TIMSS learners were taught by mathematics and science teachers who indicated that they had completed a post-secondary qualification.
- Around two-thirds of mathematics and science learners were taught by teachers who indicated that they had at least three years of teacher training and that the initial training included either mathematics or science – these teachers would be classified as qualified and knowledgeable in their subject area.
- Internationally, most teachers had at least a four-year degree qualification. The comparison with the international cadre of TIMSS teachers illustrates that the South African mathematics and science teachers are among the least qualified.

9.2. Professional development courses

- In addition to formal mathematics and science training, teachers have to update their knowledge continually.
- Internationally, about half the learners were taught by teachers who indicated that they had participated in professional development activities in the past two years.
- The type of professional development activities that most teachers participated in related to mathematics content, and pedagogy or instruction.
- South African teachers attended a higher number of professional development activities than the international average for activities related to mathematics or science content, mathematics or science curriculum, improving critical thinking, and mathematics or science assessment.
- The relatively low percentage of teachers who reported on professional development activities relating to mathematics or science pedagogy or instruction is suprising, given that C2005 introduced a different way of organising classroom activities.

10. Classrooms

The classroom setting provides the principal environment in which learning and teaching of mathematics and science takes place.

10.1. Class size

- The South African average class size of 45 was the second highest of all TIMSS participants.
- Just over half the South African learners were in classes with a class size higher than 41.
- Within the country there is a slight association, as expected, between mathematics and science achievement scores and class sizes – the scores are higher where the class size is smaller.

10.2. Textbooks

- The textbook is an important resource for the teaching and learning of mathematics and science.
- Internationally, about two-thirds of mathematics teachers and just over half the science teachers reported using the textbook as the primary basis for their lessons. Around one-third of mathematics and science teachers reported using it as a supplementary resource.
- In South Africa, the pattern was reversed and one-third of mathematics and science teachers reported that they used textbooks as the primary basis for lessons; the remaining two-thirds reported using it as a supplementary resource.

11. Schools

Educational inputs largely take place in schools. These institutions have a much greater importance for performance in poorer communities (or developing countries) than in middle-class communities (or developed countries).

11.1. Socio-economic status

- In South Africa, principals indicated that 5 per cent of learners attended schools where there are less than 25 per cent economically disadvantaged learners, while 85 per cent attended schools where there are more than 50 per cent economically disadvantaged learners.
- Internationally, the mathematics achievement score for learners in schools with few (0–10 per cent) learners from economically disadvantaged homes was 57 scale points higher than that of the learner population from economically disadvantaged homes (496 points versus 439 points).
- In South Africa, the average mathematics score for learners in schools with few economically disadvantaged learners was 479, while in schools where more than 50 per cent came from economically disadvantaged homes the score was 237 – that is, there was a difference of 242 points.
- In South Africa, economic disadvantage has a high impact on achievement scores.

11.2. School resources, climate and attendance

- About 40 per cent of South African Grade 8 learners attended schools which had a low resource base for mathematics and science teaching and learning.
- About half the learners attended schools rated by teachers and principals as having a low school climate.
- Forty-four per cent of learners attended schools rated by teachers and principals as having low school and class attendance.

- The school climate and environment for most learners does not seem to be conducive to high quality teaching and learning of mathematics and science.

The following are some implications of TIMSS 2003 for future South African research, policy and practice.

1. No single cause to explain performance

   Analysis of achievement scores within the country, and a comparison of these scores across several countries, highlights the fact that no single cause can be cited as an explanation for the performance of South African learners. The analysis is conjunctural – a combination of several factors (acting together within particular social, economic, historical and cultural contexts) produced the kinds and levels of performances observed. However, the analysis highlights several leverage points that could be used to raise mathematics and science performance in schools.

2. Improve performance: improve the school

   The performance level of learners in mathematics and science in South Africa is very low. However, this poor performance does not exist in isolation; it reflects the inequalities many learners are confronted by within the education system itself. The main challenge for South African education is to improve this system; the aim being, for the purposes of this report, to increase the (currently poor) average achievement scores in the mathematics and science learning areas. In addition, the distribution of scores needs to move from its present postion – skewed to the left – towards a more normal distribution curve. The key strategy for the improvement of mathematics and science performance is to build up the school as an institution, starting with a few targeted, better-performing schools, and then gradually expanding the number of schools. Schools are the institutions where the main educational inputs take place for the majority of learners and it is critical that they provide a quality input.

3. Quality of the professional development courses

   South African teachers attend a high number of professional development courses. These courses (offered by the Ministry of Education, universities, and non-governmental organisations) are an opportunity to provide a high quality input, and something which could facilitate improving the classroom teaching and learning. Given that this is a high-cost opportunity (the programme costs and the cost of having teachers away from the classroom) and that, so far, there is no clear evidence of the impact these courses have on performance, much more attention must be given to the quality of this intervention. Professional development courses need continual evaluation to ensure a quality input. Furthermore, it is necessary to measure the effect these courses have upon the classroom, bearing in mind that inputs of this, or any, nature must be directly aimed at improving learner knowledge and skills.

4. Teaching qualifications

   The longer-term objective of (and challenge to) the education system should be to raise the qualification of the mathematics and science teachers to the equivalent of a four-year university degree. However, the immediate challenge is to ensure that the one-third of teachers who teach mathematics and science without possessing the appropriate knowledge and skills be given the requisite training and qualifications.

A parallel challenge is to offer professional development courses introducing teachers to the new curriculum. While it is acknowledged that the training will take place over a period of time, it is crucial for investments in teacher development to be of high quality; furthermore, the return on such investments must be better than it is at present.

5. Class size

An objective of the South African education system must be to reduce the class size from the present average of 45. To achieve this will require substantial investment in financial and human resources – that is, getting more classrooms and attracting new mathematics and science graduates into the teaching profession. The Ministry of Education should develop both medium- and long-term strategies for this purpose.

6. Language of teaching and learning

There is an observable relationship between learners' lower achievement at school and the fact that they do not speak the language of the test items at home. However, as mentioned elsewhere in this report, there is a complex set of several factors affecting performance in the classroom. Therefore, the impact language proficiency has on achievement scores needs to be seen in relation to these other determining factors. Comparison of South African scores with other countries' scores, using the category of 'language spoken', suggests that language factors are embedded within other factors – socio-economic variables, the nature of teaching and, importantly, the appropriate level of cognitive demand in classroom interactions. Noting this, it is thus crucial that teaching quality and the cognitive demands made of learners are of a sufficiently high standard, as well as targeting language proficiency of learners.

7. Resources

Teachers can be supported in the classroom with the provision of high quality teaching materials. There should be textbooks for learners, paralleling what is taught in classrooms, enabling them to work independently.

8. Participating in international and national systemic studies

It is important for South Africa to participate in studies that incorporate the ability to externally benchmark performance. The choice of which cross-national study to participate in rests on two factors: its benchmarking potential, and the likelihood that it will produce a normal distribution of scores – so allowing for the generation of a model to explain performance. In addition to eliciting information from large-scale, paper-and-pencil tests, studies examining what happens inside classrooms – the teaching and learning of mathematics and science and what learners know, and can do – are also needed.

ACRONYMS AND ABBREVIATIONS

AIB	Advanced International Benchmark
C2005	Curriculum 2005
DET	Department of Education and Training
DoE	Department of Education
DPC	Data Processing Center
DST	Department of Science and Technology
EFA	Education for All
FET	Further Educational Training
GDP	gross domestic product
GET	General Education and Training
GNI	gross national income
GSCA	good school class attendance
HDI	Human Development Index
HIB	High International Benchmark
HoA	House of Assembly
HoD	House of Delegates
HoR	House of Representatives
HSRC	Human Sciences Research Council
IEA	International Association for the Evaluation of Educational Achievement
IIB	Intermediate International Benchmark
IRT	item response theory
ISC	International Study Center
LIB	Low International Benchmark
MLA	monitoring learning achievement
MLMMS	mathematics literacy, mathematics and mathematical sciences
M	Mean
MCQ	multiple-choice question
OBE	outcomes-based education
OECD	Organisation for Economic Co-Operation and Development
PIRLS	Progress in International Reading Literacy Study
PISA	Performance in International Student Achievement
PPS	probability-proportionate-to-size
PPSC	principals' perception of school climate
RNCS	Revised National Curriculum Statements
SACMEQ	Southern Africa Consortium for Monitoring Educational Quality
SCM	self-confidence in learning mathematics
SCS	self-confidence in learning science
SE	standard error

SRN	School Register of Needs
SVM	students valuing mathematics
SVS	students valuing science
TCMA	test curriculum matching analysis
TIMSS	Trends in International Mathematics and Science Study
TPSC	teachers' perception of school climate
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children's Education Fund
UNDP	United Nations Development Program

Achievement studies and TIMSS

In November 2002, about 9 000 Grade 8 learners from South African public schools participated in the Trends in International Mathematics and Science Study (TIMSS). South Africa was one of 50 countries (and educational systems) that participated in this study. TIMSS is a project of the International Association for the Evaluation of International Achievement (IEA), an organisation that has been conducting cross-national studies since 1959. The Human Sciences Research Council (HSRC) has co-ordinated and managed the South African part of the study. TIMSS 2003 is the third TIMSS that South Africa has participated in – the others being in 1995 and 1999.

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International achievement studies in mathematics and science

International studies of educational achievement have been conducted since the 1960s. There is an increasing number of studies and participating countries. There are many reasons why countries participate in multi-country and international achievement studies. Most obviously, the studies permit a comparison of performance with other countries. Participation affords access to technical expertise in measurement and analysis, which can be shared and transferred. It may also provide access to resources supporting some of the data-collection costs. Development agencies often encourage participation as a way of increasing government's accountability for improving quality and performance within the education domain.

Mathematics and/or science assessments form part of the following comparative studies: the previously mentioned Trends in International Mathematics and Science Study (TIMSS), Monitoring Learning Achievements (MLA), the Southern Africa Consortium for Monitoring Educational Quality (SACMEQ)[1] initiated studies, and Performance in International Student Achievement (PISA). The promoters of these studies argue that the studies provide information to help improve the quality of education and that cross-national comparisons have a value in benchmarking performance.

Each international achievement test has its own historical roots, its own framework for assessment, and its own sponsors. TIMSS assesses mathematics and science knowledge and skills based on the school curriculum for Grade 4 and Grade 8 learners. Since 1995, TIMSS has conducted these studies on a four-year cyclical basis. TIMSS uses the curriculum as the organising concept in considering how educational opportunities

1 Programme d'analyse des systèmes éducatifs de la CONFEMEN (PASEC) is the French equivalent of SACMEQ.

are provided to learners. This model is structured upon three aspects: *the intended curriculum*, the *implemented curriculum* and the *achieved curriculum* (Mullis et al. 2003). The IEA has commissioned the Boston College International Study Centre (now called TIMSS and PIRLS Study Center) to co-ordinate the study from Boston. Donor governments and agencies support and encourage developing countries' participation. For the TIMSS 2003 study, the World Bank supported 20 countries and the United Nations Development Program (UNDP) supported five Middle-Eastern countries. South Africa participated in TIMSS 1995, TIMSS 1999 and TIMSS 2003, at the Grade 8 level. In 1999 there were 38 participating countries, including Morocco and Tunisia from the African continent. Fifty countries (and educational systems) participated in TIMSS 2003 and the two additional African countries were Botswana and Ghana.

The MLA project, a UNESCO/UNICEF initiative, was set up in 1992 as part of the international monitoring of Education for All (EFA). MLA aims to monitor the progress of participating countries towards achieving their own EFA goals. The 1999 MLA (Africa) project report (Chinapah et al. 2000:2) indicated that the results of the MLA project may be used to assess progress towards Indicator 15 of the EFA 2000 Assessment, which is, 'the percentage of learners having reached at least Grade 4 primary schooling who master a set of nationally defined basic learning competencies'. The MLA project developed tests to measure the learning achievement of Grade 4 learners in respect of their basic learning competencies, which describes the minimum basic knowledge and analytical skills that learners should be expected to have. In 1999, MLA assessed Grade 4 learners in 18 African countries in the areas of life skills, reading and numeracy, and South Africa was one of the participating countries. In addition to assessing achievement, the MLA project notes the capacity building of national research co-ordinators and the sharing of skills among participating countries as an objective.

The PISA study is steered by the governments of participating countries through the Organisation for Economic Co-operation and Development (OECD). The PISA survey was first conducted in 2000 and is administered every three years. PISA (an internationally standardised assessment instrument) assesses, on a cyclical basis, competencies in mathematical and scientific skills and reading literacy. PISA is based on the model of lifelong learning and assesses 15 year olds' capacity to use their knowledge and skills to meet real-life challenges, rather than how well they have mastered a specific school curriculum. In all PISA cycles, the domains of reading, and mathematical and scientific literacy are assessed. The main focus of PISA 2000 was on reading literacy; PISA 2003 concerned mathematical literacy and the domain of problem solving, while the focus of PISA 2006 will be on scientific literacy. Forty-three countries (of which one-third were non-OECD countries) participated in PISA 2000; 41 countries participated in PISA 2003, and at least 57 countries will participate in PISA 2006.

SACMEQ, a collaborative network of 15 African Ministries of Education, is a long-term initiative aimed at continuous assessment and monitoring of education quality and learning achievement at various levels of the education system. The programme is also aimed at making informed policy suggestions towards improving the provision of quality education. The SACMEQ project is designed to build the capacity of educational planners in Ministries of Education when undertaking large-scale educational policy research. SACMEQ I Project (1995–1999) involved seven Ministries of Education and focused on reading. SACMEQ II Project (2000–2003) involved 14 Ministries of Education, including South Africa's, and assessed Grade 6 mathematics and reading achievement in 15 Southern African countries.

Benefits and limitations of achievement studies

There has been much written about the concerns and value of conducting international and national achievement studies (Goldstein 1995; Beaton et al. 1999; Shorrocks-Taylor & Jenkins 2000; Kellaghan & Greaney 2001; Taylor et al. 2003). The South African debates surrounding such studies mirror the international debates, with the additional concern that these studies do not provide information on every area of South Africa's education transformational goals, namely, access, redress, equity and quality. More particularly, for South Africa, it may be that success should be judged across these areas, not just in terms of aggregate levels of performance. Participating in international, cross-national achievement studies has both benefits and limitations. Reddy (2005) discussed this in detail in the article 'Cross National Achievement studies: Learning from South Africa's participation in International Mathematics and Science Study.'

The main concerns regarding international comparative studies relate to the following. Firstly, the comparisons or the league table presentation of the results could take on a competitive edge, with negative consequences. TIMSS uses the curriculum as the major organising concept and a way of explaining achievement. However, this approach raises concerns, as it may give rise to pressure for the gradual convergence of differing curricula. In poorer countries, this increased focus on curriculum reform may well be at the expense of engaging in more critical areas of reform, for example, the provision of a basic infrastructure. Some countries (such as England and the United States) are concerned about the possible negative consequences of the TIMSS results trying to shape the national curricula and return the curriculum to a 'back-to-basics' approach, to the detriment of areas in which children are doing well. Furthermore, although instruments are intended to be designed on the basis of consensus among countries, the instruments may be influenced by, and better suited to, the more influential countries. In addition, the background information may not be able to explain what causes higher or lower achievement. For example, the contribution to variations in achievement due to school and home factors in richer and poorer countries is different and needs to be accommodated in the instruments. Large-scale assessment studies are expensive and need both financial and human resources. For poorer countries, especially, there are opportunity costs linked to participation in such studies. Achievement tests are generally paper-and-pencil tests and the mode of testing may influence what participants say about performance.

Comparative achievement studies, whether loved or hated, catalyse a great deal of debate when the results are published, which can, in turn, result in beneficial action being taken. Firstly, for example, the publication of the TIMSS 1999 results in South Africa provoked widespread debate and was one of the events that helped bring about an increased allocation of resources to science and mathematics at school level. Thus, the publication of comparative achievement results can be used as a lever for reform. Secondly, TIMSS has the potential to harness positive changes in countries where policy-making may not be informed or influenced by key research, or in countries where there are no robust civil society structures lobbying for change. In countries with outdated curricula and an insufficiently strong academic voice advocating change, it is these international agendas that can, sometimes, effect this change. Thirdly, comparison of performance with countries of similar context and histories could provide a basis for benchmarking a country's individual performance and thus expose the strengths and weaknesses of its education system. Fourthly, not all countries have the resources and capabilities to organise national studies. The international research organisations possess an expansive repertoire of technical skills suited to the design and management of these studies. These resources could be used to assist countries which lack these skills.

Achievement studies in South Africa

Countries undertake national assessments and systemic evaluation of their educational system to monitor the performance of that system, improve accountability, and identify opportunities for improving learning outcomes. The National Education Policy Act of 1996 makes provision for the DoE to conduct a systemic evaluation. The main objective of systemic evaluation is 'to assess the effectiveness of the entire system and the extent to which the vision and goals of the education transformation process are being achieved by it'. Systemic evaluation determines the strengths and weaknesses of the learning system on a periodic basis and provides feedback to all the role players, in order that appropriate action may be taken to improve the performance of the learning sites and learning systems.

In 2001, South Africa undertook a systemic evaluation at the end of the Foundation Phase of schooling. Grade 3 learners were assessed in the areas of literacy, numeracy and life skills. In 2004, the systemic evaluation was conducted at the Grade 6 level in literacy, science and mathematics. According to DoE policy, they will conduct a systemic evaluation at Grade 9 level in 2007.

South Africa has participated in several multi-country studies and undertaken national and provincial assessment studies. In many of these studies low achievement scores in mathematics and science have been recorded; a situation causing considerable concern. A response to low scores could be that the study is inappropriate for the country in question. However, with consistently low scores, it is more useful to shift the debate to centre on how we use the achievement information to inform policy and practice issues in the country. The HSRC decided to co-ordinate the South African participation in TIMSS (with its various limitations) in order to benchmark its performance against other countries, and to provide comparative information relevant to the design and development of strategies for rasing mathematics and science standards. The data and the national report provide information that may be of use to national policymakers and practitioners.

TIMSS

TIMSS is a project of the IEA. The main aim of TIMSS 2003 was to provide trend information on learner achievement in mathematics and science. TIMSS 1995 was the first in a series of mathematics and science assessments to be conducted every four years for the provision of this trend information. Boston College's International Study Center for TIMSS and PIRLS[2] manages the international project activities. The other organisations working closely with Boston College are Statistics Canada in Ottawa, The IEA Data Processing Center in Hamburg (Germany), and The Educational Testing Services in Princeton, New Jersey, USA.

In TIMSS, learners completed achievement tests in mathematics and science and answered questions on their home background, prior experiences and their attitudes towards

2 PIRLS is the IEA's Progress in International Reading Literacy Study.

mathematics and science. Mathematics and science teachers completed questionnaires on, inter alia, their teaching preparations, teaching styles, professional development, and attitudes towards science and mathematics. Principals completed questionnaires on school characteristics, parental involvement, Grade 8 teaching and teachers of mathematics and science, learner behaviour, and resources and technology.

The Assessment Technology and Education Evaluation Research Programme in the HSRC conducted TIMSS 2003 in South Africa. The HSRC had also conducted TIMSS 1995 and TIMSS 1999. Financial support for the study came from two sources: the World Bank provided the IEA with funds to assist some countries with the participation costs, South Africa being one of these countries. In-country costs were met by a parliamentary grant the Department of Science and Technology (DST) allocated to the HSRC.

TIMSS is one of the few studies providing national, quantitative data on the state of the South African education system. In-country there are many small-scale, qualitative studies providing information on aspects of science and mathematics education. TIMSS 1995 offered the first national analysis of learner achievement, and the subsequent cross-national studies have provided systemic information and external benchmarking of the South African educational system.

Countries participating in the TIMSS 2003 Grade 8 study

TIMSS 2003 involved 46 countries and four benchmarking participants. The 46 countries were:

Armenia
Australia
Bahrain
Belgium (Flemish)
Botswana
Bulgaria
Chile
Chinese Taipei
Cyprus
Egypt
England
Estonia
Ghana
Hong Kong, SAR
Hungary
Indonesia
Iran, Islamic Republic of
Israel
Italy
Japan
Jordan
Korea, Republic of
Latvia
Lebanon
Lithuania
Macedonia, Republic of
Malaysia
Moldova, Republic of
Morocco
Netherlands
New Zealand
Norway
Palestinian National Authority
Philippines
Romania
Russia Federation
Saudi Arabia
Scotland
Serbia
Singapore
Slovak Republic
Slovenia
South Africa
Sweden
Tunisia
United States

The four benchmarking participants were:

Basque Country, Spain
Indiana State, US
Ontario Province, Canada
Quebec Province, Canada

Summary

Since 1994, South Africa has participated in cross-national achievement studies and, since 2001, conducted national achievement studies. Cross-national studies have both benefits and limitations. The external benchmarking the studies offer, means individual countries can critically assess their own educational standing and performance, which represents a definite benefit. Furthermore, an examination of countries displaying similar recorded characteristics can be useful in generating or discarding hypotheses of what may cause improved performance. Regarding limitations, the principal disadvantage could be that if group performance is low, there could be a 'floor effect' of scores; thus, one could not use the data to develop effective models explaining performance.

CHAPTER 2

TIMSS design and methodology

This chapter will provide an overview of the design of the study. TIMSS was a large-scale comparative study involving 50 participants. TIMSS primarily measured learner achievement in mathematics and science, as well learner beliefs and attitudes towards these subjects. The study also investigated curricular intentions and school and classroom environments. Since TIMSS was an international exercise, there was a need for a common framework to ensure comparability of the results across the different countries, and a need to develop instruments that would be useful to each of the participating countries. To this end, TIMSS International Study Center (ISC) organised a number of meetings with the national research co-ordinators to seek consensus on the framework and items to be included in the various instruments. In addition, TIMSS produced manuals to assist in administrating the study in the different countries.

This chapter will provide a description of the study's design and framework. This description is drawn mainly from two TIMSS publications: *TIMSS Assessment Frameworks and Specifications 2003* (Mullis et al. 2003) and *TIMSS 2003 Technical Report* (Martin, Mullis & Chrostowski 2004). The chapter will also describe how the study was conducted in South Africa.

TIMSS conceptual framework

TIMSS uses the curriculum, broadly defined, as the organising principle in how educational opportunities are provided to learners. The curriculum model has three aspects: the *intended curriculum*, the *implemented curriculum* and the *attained curriculum*.

The *intended curriculum* refers to the mathematics and science knowledge that society intends learners to learn, that is, the curriculum at the national or system level. Information from this level provides a national, social and an educational context. The *implemented curriculum* refers to how the educational system should be organised to facilitate this learning; what is actually taught in classrooms, who teaches it, and how it is taught. Data collected here provides information on the school, teacher and classroom context. The *attained curriculum* refers to what it is that learners have learned and what they think about these subjects. Data collected here provides information about learner outcomes and characteristics.

Instruments

Using the above model, TIMSS used mathematics and science achievement tests to describe what learners have learnt. The learner, teacher, and principal questionnaires obtained information on the structure and content of the intended curriculum in mathematics and science; the preparation, experience and attitudes of teachers; the mathematics and science content actually taught; the instructional approaches used; the organisation and resources of schools and classrooms; and the experiences and attitudes of the learners in the schools.

Achievement instruments

TIMSS assessed in the areas of mathematics and science. TIMSS 2003 was framed by two organising dimensions: a content domain and a cognitive domain. The content domain defined the specific mathematics and science subject matter covered by the assessment, while the cognitive domain defined the set of behaviours expected of learners engaged in mathematics or science.

The content domains that framed the mathematics curriculum were: number, algebra, measurement, geometry and data. The cognitive domains for mathematics were: knowing facts and procedures, using concepts, solving routine problems, and reasoning. The content domains that framed the science curriculum were: life sciences, chemistry, physics, earth science and environmental science. The cognitive domains were: factual knowledge, conceptual knowledge, and reasoning and analysis. Table 2.1 outlines the content and cognitive domains for mathematics. Table 2.2 outlines the content and cognitive domains for science.

Table 2.1: Mathematics content and cognitive domains and the proportion of assessment for each domain

Content domain	Topic	Per cent assessment
Number	Whole numbers Fractions and decimals Integers Ratio, proportion and percentages	30%
Algebra	Patterns Algebraic expressions Equations and formulae Relationships	25%
Measurement	Attributes and units Tools, techniques, formulae	15%
Geometry	Lines and angles Two- and three-dimensional shapes Congruence and similarity Location and spatial relationships Symmetry and transformations	15%
Data	Data collection and organiszation Data representation Data interpretation Uncertainty and probability	15%

Cognitive domain	Learner behaviour	Per cent assessment
Knowing facts and procedures	Recall Recognise/identify Compute Use tools	15%
Using concepts	Know Classify Represent Formulate Distinguish	20%
Solving routine problems	Select Model Interpret Apply Verify and check	40%
Reasoning	Hypothesise/conjecture/predict Analyse Evaluate Generalise Connect Synthesise/integrate Solve non-routine problems Justify/prove	25%

Table 2.2: Science content and cognitive domains and the proportion of assessment for each domain

Content domain	Topic	Per cent assessment
Life sciences	Types, characteristics and classification of living things Structure, function and life processes in organisms Cells and their functions Development and life cycles of organisms Reproduction and heredity; diversity, adaptation and natural selection Ecosystems and human health	30%
Chemistry	Classification and composition of matter Particulate structure of matter Properties and uses of water Acids and bases Chemical change	15%

Content domain	Topic	Per cent assessment
Physics	Physical states and changes in matter	
	Energy types, sources and conversions	
	Heat and temperature	
	Light	25%
	Sound and vibration	
	Electricity and magnetism	
	Forces and motion	
Earth science	Earth's structure and the physical features	
	Earth's processes, cycles and history	15%
	Earth in the solar system and the universe	
Environmental science	Changes in population	
	Use and conservation of natural resources	15%
	Changes in environments	
Cognitive domain	**Learner behaviour**	**Per cent assessment**
Factual knowledge	Recall/recognise	
	Define	
	Describe	30%
	Use tools and procedures	
Conceptual understanding	Illustrate with examples	
	Compare/contrast/classify	
	Represent/model	
	Relate	35%
	Extract/apply information	
	Find solutions	
	Explain	
Reasoning and analysis	Analyse/interpret/solve problems	
	Integrate/synthesis	
	Hypothesise/predict	
	Design/plan	35%
	Collect/analyse/interpret data	
	Draw conclusions	

The mathematics and science tests were developed internationally in a collaborative manner. Two different types of questions (multiple-choice questions and constructed-response questions) were included in the pool of TIMSS questions. The overriding principle in the construction of achievement tests for TIMSS 2003 was to produce assessment instruments that would generate valid and reliable data. To achieve a valid assessment of the two subjects, a substantial number of assessment items was needed. To accommodate the large number of items required in the limited testing time available (about 90 minutes per learner), TIMSS used a matrix-sampling technique. This technique involved dividing the item pool among a set of 12 learner booklets. The questions were assigned to the booklets in such a way that the combined responses of individual learners provided a comprehensive picture of the entire learner population's achievement.

Each learner completed only one of the 12 achievement booklets for the study. These were distributed equally among the class learners, in order that approximately equal numbers of learners responded to each booklet.

Background questionnaires

TIMSS included information on the educational contexts within which learners learn mathematics and science. Thus, TIMSS administered questionnaires to curriculum specialists, learners in participating schools, their mathematics and science teachers, and their school principals.

Curriculum questionnaires were designed to collect information on the organisation of each country's mathematics and science curricula, and on the subjects' content intended to be covered up to Grade 8. The national research co-ordinator in each country was responsible for the completion of these questionnaires.

Learner questionnaires were completed by each learner taking the assessment. The questionnaires focused on aspects of learners' home and school lives, classroom experiences, self-perception and attitudes about mathematics and science, homework and out-of-school activities, computer use, home educational supports, and other basic demographic information.

Mathematics teacher questionnaires and *science teacher questionnaires* were given to the maths and science teachers in the TIMSS classes. These questionnaires provided information on the teachers' backgrounds, beliefs, attitudes, educational preparations, and teaching loads, as well as the pedagogic approach adopted in the classroom. The questionnaires examined characteristics of the classes tested in TIMSS: instructional time, materials, activities for teaching mathematics and science, promoting learners' interest in the subject, assessment practices, and home-school connections. Included in the *learner* and *teacher questionnaires* were additional questions specific to South African learners and teachers.

School questionnaires were answered by the school principals. These asked about enrolment and staffing, resources available to support mathematics and science instruction, school goals, the role of the school principal, instructional time, and the school climate.

All questionnaires were designed to take about 30 minutes to complete.

Sampling

The TIMSS sampling design was a three-stage stratified cluster design (*TIMSS 2003 School Sampling Manual*), and involved:

- Selecting a sample of schools from all eligible schools;
- Randomly selecting a mathematics and science class from each sampled school; and
- Sampling learners within a sampled class in cases where the number of learners in a class is greater than 40.

Selecting a sample of schools for test administration

TIMSS is a population survey and the sample of learners is representative of the population from which it is drawn – in South Africa, these are Grade 8 learners. For South Africa, the SRN database was used to select the sample of schools. Statistics Canada assisted in selecting the random sample. While TIMSS recommended a minimum sample size of 150 schools and 4 500 learners, South Africa oversampled the number of schools and learners in order to generate provincial statistics. The sample size was 265 schools and approximately 9 000 learners across the nine provinces.

The sample was explicitly stratified by two dimensions:
- By province; and
- By the language of teaching and learning (English and Afrikaans were the only languages of instruction chosen by schools and indicated in the SRN 2000.)

It was anticipated that a 100 per cent participation rate of selected schools might not be possible. To maximise the number of schools participating, a first- and second-replacement school, displaying similar characteristics to the originally sampled study school, was also selected.

Table 2.3 indicates the number of schools sampled, and the number of schools and learners that participated in TIMSS 2003 in South Africa. Of the 265 schools sampled, ten schools withdrew at a late stage and 14 were replacement schools. Appendix 1 of this report provides a GIS plot of TIMSS 2003 participating schools.

Table 2.3: TIMSS Grade 8 schools sampled, schools in which instruments were administered, and number of learners

Province	Schools sampled	Sampled schools participating	First replacement school	Second replacement school	Total schools	Total learners
KwaZulu-Natal	48	43	2	1	46	1 632
Eastern Cape	33	29	3	1	33	943
Western Cape	25	22	1		23	813
Limpopo	32	31			31	1 145
Free State	25	24	1		25	867
Mpumalanga	25	23	1		24	962
North West	25	25			25	946
Gauteng	27	20	3		23	774
Northern Cape	25	24	1		25	870
Total	265	241	12	2	255	8 952

Selecting a class for the administration of TIMSS

Once the schools were selected, permission was sought from the school principal and the district offices for the administration of the TIMSS instruments. The next step was to select one intact Grade 8 class. The TIMSS design involved the selection of intact classes, rather than a random sample of learners from across the grade. Having an intact class ensured that the mathematics and science teacher could be matched. Furthermore, the beliefs and practices of the teachers could provide contextual information that might help explain the achievements and attitudes of their learners. However, it must be remembered that the teachers who took part in the studies were not a representative sample; rather, they were mathematics and science teachers who taught a representative sample of learners. Furthermore, the choice of intact classes meant that it was not possible to compare across schools.

Schools submitted a list of the number of Grade 8 classes. Using a systematic probability-proportionate-to-size (PPS) technique; one class was randomly selected for test administration. The assumption was that the average class size would be 40 and that all learners in the class would participate in the study.

Sampling learners within a sampled class

All learners within a classroom were expected to take part in the TIMSS assessment. For large class sizes (over 50 learners), we sub-sampled from the whole class for a group of 40 learners. This was done using a systematic sampling method, whereby all learners in a sampled classroom were assigned equal selection probabilities.

Field testing of TIMSS achievement items

After each TIMSS assessment cycle, some items are released for public use while the others are kept secure to measure trends over time. The development of new items for TIMSS 2003 started with the revision of the existing frameworks to reflect changes in curriculum and instruction in participating countries.

To replace assessment items that had been released, countries submitted items for review by subject specialists. The ISC conducted an item-writing training workshop for countries intending to submit items for possible inclusion in TIMSS 2003. A manual on *Item-writing Guidelines for TIMSS* was developed and distributed. The primary purpose of the manual, in conjunction with the workshop, was to provide information and advice on writing and reviewing items for the TIMSS tests.

Each country was responsible for the development of items in the subject of their choice. South Africa developed science items during the first two weeks in July 2001. The items and scoring guides from each country were reviewed and revised by the Science and Mathematics Item Review Committee, according to TIMSS criteria.

The new items were pilot-tested in 2002 in most of the participating countries. The piloting of the new items was co-ordinated and supported by the TIMSS and PIRLS ISC. South Africa tested Grade 9 learners instead of Grade 8 learners, since the TIMSS 2003 field test took part during the first half of the academic year. Intact mathematics classes were sampled and all learners in the mathematics class also took science as well. The mathematics and science teachers of these classes were asked to complete the teacher questionnaires. The sample for the field test comprised 25 schools from Gauteng.

Results from the pilot test from each country were pooled and used to evaluate item difficulty, how well items discriminated between high- and low-performing learners, the effectiveness of distracters in multiple-choice items, scoring suitability and reliability for constructed-response items, and evidence of bias towards or against participating countries or in favour of boys or girls. The suitability of the item was determined for the international sample, rather than for specific countries.

Main administration of TIMSS

Each country collected its own data. Procedures for data collection are outlined in *TIMSS Survey Operations Manuals*. These manuals have been designed to ensure that high-quality, internationally comparable data will be available for analysis. Training was also provided by the international project team to explain survey operations. If a country deviated from the prescribed procedures without prior approval, it ran the risk of losing the ability to measure trends properly, or to compare data with other countries participating in the study. TIMSS instruments were administered at the end of the Grade 8 academic year – for southern-hemisphere countries the TIMSS administration was conducted between October and November 2002, and for the northern-hemisphere countries the administration took place between March and May 2003.

Test administration in South Africa was carried out from 21 October to 1 November 2002. Schools were telephoned and appointments set up. School staff were used to assist with the class lists and logistical arrangements, such as identifying and preparing testing locations. An outside agency (AC Nielsen and Mictert) was chosen to administer the instruments in schools. Each of the data-collection agencies had their teams of data collectors. At the end of the data-collection process, all instruments and questionnaires were returned to the HSRC.

Training of data collectors

The HSRC trained the data collectors on administering TIMSS in the schools. The TIMSS ISC had prepared a manual for the training of data collectors.

Quality assurance of fieldwork

Each country was responsible for conducting quality-control procedures. When data was collected, a team of HSRC researchers sampled about 15 per cent of the schools for quality assurance. In addition, there was a quality control observer appointed by the ISC, who visited ten schools. The ISC also developed manuals for the monitors.

Scoring of constructed responses

The open-ended items were scored and coded. A scoring guide was developed for every open-ended item included in the TIMSS assessment. HSRC researchers were responsible for co-ordinating and monitoring the scoring and for coding the open-ended items. One HSRC researcher was trained by the TIMSS & PIRLS ISC in the coding system employed by TIMSS. A group of mathematics and science teachers was trained in data scoring – according to the data-scoring guidelines provided by the ISC. These teachers were responsible (in November and December 2002) for coding and scoring the open-ended items. To gather within-country agreement among coders, systematic sub-samples of the responses of at least 100 learners to each constructed response items were coded independently by two coders. Information on scoring and coding reliability was documented by the ISC and used to calculate cross-country agreement among coders.

To measure trends over time, TIMSS included items from 1995 and 1999 in TIMSS 2003. To ensure that constructed-response items used in 1999 were scored in the same way in 2003, participating countries sent scored booklets from the 1999 data–collection exercise to the IEA Data Processing Center (DPC), where they were scanned and the data stored. The 2003 data scorers re-scored the TIMSS 1999 responses. Scores allocated by 2003 scorers were compared with those from 1999 to check scoring consistency during this period.

Data capture and cleaning

Data capture

The IEA DPC in Hamburg, Germany (a partner with Boston College on TIMSS), provided an integrated computer programme for data entry and data verification, known as Data Entry Manager (WinDEM). WinDEM included a series of checks and verification procedures that helped ensure the quality of the data as it was being entered. An outside agency (AC Nielsen) was contracted to capture the data. The agency staff were trained in using the software. During the data-capturing process, 25 per cent of the data was recaptured for verification purposes. The data-capturing agency had to provide data with an error rate less that 0.1 per cent after verification.

Data cleaning

The data underwent a rigorous cleaning process at the HSRC, using software supplied by the DPC. The cleaning process included the following:

- Document and structure check;
- Identification variable cleaning;
- Linkage check; and
- Resolving inconsistencies in background questionnaire data.

When all the data passed the WinDEM quality-control checks, it was dispatched to the DPC for further checking and processing.

Data processing

TIMSS reported trends in learner achievement in both the general areas of mathematics and science and the major content areas related to each subject. As each learner responded to only part of the assessment, TIMSS relies primarily on item response theory (IRT) scaling methods to provide estimates of what learner achievement would be if they had responded to all the test items.

Scaling

The IRT scaling uses the multiple imputations, or 'plausible values', method to obtain proficiency scores in mathematics and science and their content areas for all learners, even though each learner responded to only a part of the assessment item pool (Yamamoto & Kuick 2000). IRT analysis provided a common scale on which performance could be compared across countries. In addition to providing a basis for estimating mean achievement, scale scores provide estimates of how learners within countries vary and information on percentiles of performance.

Estimation

To improve reliability, TIMSS scaling methodology drew upon information gained on learners' background characteristics, as well as their responses to the achievement items. This approach, known as 'conditioning', enables reliable scores to be produced, even though individual learners responded to relatively small subsets of the total mathematics or science pool. Rather than estimating learner scores directly, TIMSS combined information about item characteristics, learner responses to the items that they took and learner background information, to estimate learner achievement distributions. Having determined the overall achievement distribution, TIMSS estimated each learner's achievement, conditional on the learner's responses to the items that they took and the learner's background characteristics. To account for error in this imputation process, TIMSS drew five such estimates, or 'plausible values', for each learner on the scales.

Reporting TIMSS achievement scores

The TIMSS scale average over the countries was set at 500, and the standard deviation at 100. In addition to scales for mathematics and science overall, TIMSS created IRT scales for each of the content domains for the 2003 data.

The *TIMSS 2003 International Mathematics Report* (Mullis et al. 2004) and the *TIMSS 2003 International Science Report* (Martin, Mullis, Gonzales & Chrostowski, 2004) summarised learners' mathematics and science achievement in each participating country. TIMSS 2003 also collected information about the homes, schools, classrooms and teachers of the participating learners, as well as the mathematics and science curriculum in each country. The TIMSS 2003 international mathematics and science reports summarised much of this information, combining data into composite indices and showing an association with achievement, where appropriate. These two international reports form the basis of the South African TIMSS Report.

South African mathematics achievement in an international context

This chapter summarises the achievement of the TIMSS 2003 mathematics assessment for each of the participating countries, and contextualises the performance of South African learners in relation to the 50 study participants. This overview is based on trends in the TIMSS 2003 report (Mullis et al. 2004).[1] In addition to presenting the international comparative results, a comparison of results for the participating group of African countries is given. There is also a discussion of the performance trend from 1999 to 2003, an examination of performance as it relates to gender, and an analysis of performance at the different performance benchmarks.

Mathematics achievement of participating countries in TIMSS 2003

Figure 3.1 presents the mathematics achievement distribution for each of the participating countries. TIMSS used IRT methods to calculate the achievement scores. A scale of 800 points and a standard deviation of 100 points was used. The international average was computed by averaging the mean scores of each of the participating countries. In Figure 3.1, average scores are arranged from the highest to the lowest. The results show substantial differences in mathematics achievement between the highest and lowest performing countries, from an average of 605 for Singapore to 264 for South Africa. Thirty countries achieved average mathematics scores significantly higher than the international average and 18 countries achieved scores significantly lower than the international average. The five highest performing countries for mathematics were: Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei and Japan. The five lowest performing countries were: Philippines, Botswana, Saudi Arabia, Ghana and South Africa.

Figure 3.1 illustrates the broad range of achievement both within and across the countries assessed. Achievement for each country is shown at the 25th and 75th percentiles, as well as the 5th and 95th percentiles. Each percentile point indicates the percentage of learners performing below and above that point on the scale. For example, 25 per cent of the learners in each country performed below the 25th percentile and 75 per cent performed above the 25th percentile. The range between the 25th and 75th percentiles represents performance by the middle half of the learners. Performance at the 5th and 95th percentile represents the extremes in lower and higher achievement. The range of performance between these two score points, which included 90 per cent of the population, is approximately 270 to 300 points in most countries. The dark boxes at the midpoints of the distributions show the 95 per cent confidence intervals around the average achievement in each country.

As shown in Figure 3.1, the average scale score for South African Grade 8 learners was the lowest at 264 (SE = 5.5), and this was significantly lower than the international average scale score (Mean [M] = 467, SE = 0.5). In comparing individual countries, the

1 This report is available at: http://www.timss/bc/edu.

South African average scale score was not statistically different from that of Ghana, but it was significantly lower than the remaining participating countries.

Apart from the substantial differential in mathematics achievement scores between the highest performing country (Singapore) and South Africa, it is interesting to observe the variation of scores within countries. This variation was examined using the range of scores between the 5th and 95th percentiles. A striking feature of Figure 3.1 includes the fact that Singapore's average performance exceeds South African performance at the 95th percentile – this means that only the most proficient learners in South Africa approached the average proficiency of Singaporean learners. Secondly, of all the countries participating, South Africa had the widest range of scores between the 5th and 95th percentiles – a difference of approximately 360 points. This suggests that South Africa has some learners who perform very poorly and some who perform very well.

When interpreting the comparative results presented in this report, it is important to remember that each country's result is an estimate of the total population value, inferred from the result obtained from the sample of learners tested. Because it is an estimate, it is subject to some potential level of error. The variability of the average score is given by the SE of the average, presented in the tables. We can say with 95 per cent confidence that the true population average lies within about 2 standard errors of the sample average. Standard errors are influenced by the size of the sample, the design of the sample, and the variation of scores in the sample.

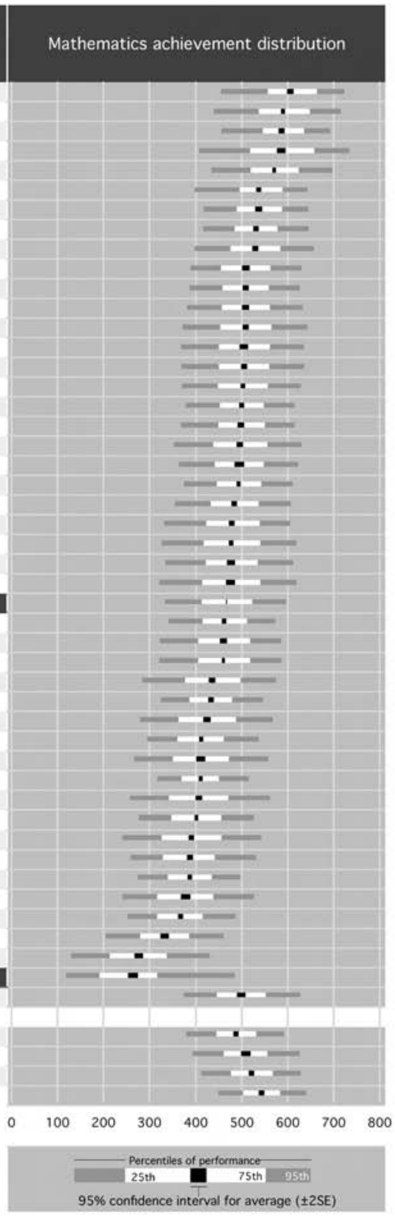
To illustrate the use of standard errors with the average, we can look at South Africa's score. South Africa had an average score of 264 with an SE of 5.5. This means that the average score for the population of Grade 8 learners in South Africa lies between 258.5 and 269.5.

To help interpret scores of the different countries, Figure 3.1 also includes the years of formal schooling and the average age of the learners assessed in each of the participating countries. Most countries assessed the learners at the end of their eighth year of schooling. The international average age of the learners assessed is 14.5 years. Learners in some Eastern European countries start school later and so tended to be older. Learners were older in many African countries, where they may have started school later or had their schooling interrupted.

Not all countries have similar socio-economic conditions. Figure 3.1 includes the value of the HDI for each of the participating countries. This index, calculated by the UNDP has a minimum value of 0 and a maximum value of 1. The index is a summary measure of human development in a country and is constructed from three dimensions: values for life expectancy at birth, knowledge – constructed from the adult literacy rate and combined primary, secondary and tertiary gross enrolment rates – and standard of living as measured by the per capita gross domestic product (GDP). TIMSS countries with an HDI value greater than 0.9 included Australia, Belgium, England, Israel, Japan, Norway and the United States. The HDI for South Africa was 0.684. Other TIMSS countries with an HDI less than 0.7 were Indonesia (0.682), Botswana (0.614), Morocco (0.606), and Ghana (0.567).

Figure 3.1 Distribution of mathematics achievement

Countries	Years of schooling*	Average age	Average scale score		Human Development Index**
Singapore	8	14.3	605 (3.6)	h	0.884
Korea, Rep. of	8	14.6	589 (2.2)	h	0.879
Hong Kong, SAR	8	14.4	586 (3.3)	h	0.889
Chinese Taipei	8	14.2	585 (4.6)	h	–
Japan	8	14.4	570 (2.1)	h	0.932
Belgium (Flemish)	8	14.1	537 (2.8)	h	0.937
Netherlands	8	14.3	536 (3.8)	h	0.938
Estonia	8	15.2	531 (3.0)	h	0.833
Hungary	8	14.5	529 (3.2)	h	0.837
Malaysia	8	14.3	508 (4.1)	h	0.790
Latvia	8	15.0	508 (3.2)	h	0.811
Russian Federation	7 or 8	14.2	508 (3.7)	h	0.779
Slovak Republic	8	14.3	508 (3.3)	h	0.836
Australia	8 or 9	13.9	505 (4.6)	h	0.939
United States	8	14.2	504 (3.3)	h	0.937
Lithuania	8	14.9	502 (2.5)	h	0.824
Sweden	8	14.9	499 (2.6)	h	0.941
Scotland	9	13.7	498 (3.7)	h	0.930
Israel	8	14.0	496 (3.4)	h	0.905
New Zealand	8.5–9.5	14.1	494 (5.3)	h	0.917
Slovenia	7 or 8	13.8	493 (2.2)	h	0.881
Italy	8	13.9	484 (3.2)	h	0.916
Armenia	8	14.9	478 (3.0)	h	0.729
Serbia	8	14.9	477 (2.6)	h	–
Bulgaria	8	14.9	476 (4.3)	h	0.795
Romania	8	15.0	475 (4.8)		0.773
International avg.	8	14.5	467 (0.5)		–
Norway	7	13.8	461 (2.5)	l	0.944
Moldova, Rep. of	8	14.9	460 (4.0)		0.700
Cyprus	8	13.8	459 (1.7)	l	0.891
Macedonia, Rep. of	8	14.6	435 (3.5)	l	0.784
Lebanon	8	14.6	433 (3.1)	l	0.752
Jordan	8	13.9	424 (4.1)	l	0.743
Iran, Islamic Rep. of	8	14.4	411 (2.4)	l	0.719
Indonesia	8	14.5	411 (4.8)	l	0.682
Tunisia	8	14.8	410 (2.2)	l	0.740
Egypt	8	14.4	406 (3.5)	l	0.648
Bahrain	8	14.1	401 (1.7)	l	0.839
Palestinian Nat'l Auth.	8	14.1	390 (3.1)	l	0.731
Chile	8	14.2	387 (3.3)	l	0.831
Morocco	8	15.2	387 (2.5)	l	0.606
Philippines	8	14.8	378 (5.2)	l	0.751
Botswana	8	15.1	366 (2.6)	l	0.614
Saudi Arabia	8	14.1	332 (4.6)	l	0.769
Ghana	8	15.5	276 (4.7)	l	0.567
South Africa	8	15.1	264 (5.5)	l	0.684
England	9	14.3	498 (4.7)	h	0.930
Benchmarking participants					
Basque Country, Spain	8	14.1	487 (2.7)	h	–
Indiana State, US	8	14.5	508 (5.2)	h	–
Ontario Province, Can.	8	13.8	521 (3.1)	h	–
Quebec Province, Can.	8	14.2	543 (3.0)	h	–



Notes:
* Represents years of schooling counting from the first year of ISCED Level 1.
** Taken from the *Human Development Report 2003*: 237–240. (UNDP 2003)
Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year.
Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.
A dash (–) indicates comparable data are not available.
h Country average significantly higher than international average.
l Country average significantly lower than international average.

South Africa in relation to other African countries

The TIMSS 2003 study included six African countries. These were: Botswana, Egypt, Ghana, Morocco, Tunisia and South Africa. Morocco, Tunisia and South Africa had participated in TIMSS 1999, while the other three made their debut in TIMSS 2003. A comparison of these countries is sensible because other variables, together with mathematics achievement scores, can provide a more contextualised perspective. Table 3.1 provides information on key indicators in these countries.

Table 3.1: Scale scores and key indicators of African country participants in TIMSS 2003

	Average math scale score (SE)	Population (millions)	Life expectancy (years)	Net enrolment (primary)	Net enrolment (secondary)	GNI per capita in US$
Tunisia	410 (2.2)	9.8	73	97	68	1 990
Egypt	406 (3.5)	66.4	69	90	78	1 470
Morocco	387 (2.5)	29.6	68	88	31	1 170
Botswana	366 (2.6)	1.7	38	81	55	3 010
Ghana	276 (4.7)	20.3	55	60	30	270
South Africa	264 (5.5)	45.3	46	90	62	2 500

Sources: UNDP 2003, cited in Mullis et al. (2004)

Table 3.1 illustrates the differences, in the six African countries, on indicators which could influence education outcomes. For example, the population of Botswana is 1.7 million, whereas the number of students in the South African education system is 12 million; in Ghana, 30 per cent of the secondary learners of the age cohort who are supposed to be in secondary school are in school, whereas in South Africa the net enrolment rate in secondary schools is 62 per cent. However, it is worrying that South Africa has one of the highest gross national incomes (GNI in US dollars) per capita of the group, yet has the lowest average mean score in mathematics. Table 3.1 suggests that the explanations for learner achievement cannot be provided by a single indicator – it is the interaction of a number of variables that produces a particular outcome.

Changes in mathematics achievement between TIMSS 1999 and TIMSS 2003

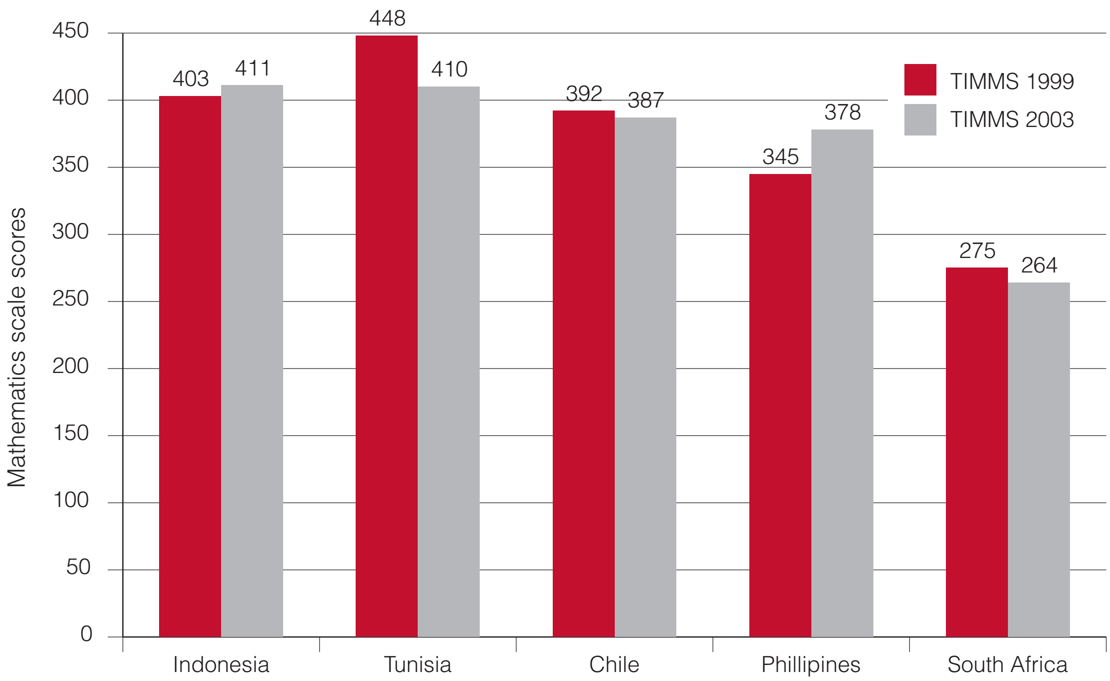
There are some countries who participated in both TIMSS 1999 and TIMSS 2003. For these countries it was possible to track the changes in performance over these two time periods. The international mathematics average score in TIMSS 1999 was 487 (SE = 0.7) and in TIMSS 2003 it was 467 (SE = 0.5).[2]

Figure 3.2 presents national comparisons for the two assessment periods for the five lowest performing countries. The mathematics scale scores for Tunisia were significantly

2 One cannot compare the international averages because there were different countries who participated in the different years.

lower (by 38 points) between TIMSS 1999 and TIMSS 2003. The Philippines, however, scored significantly higher in TIMSS 2003 than TIMSS 1999. For Indonesia, Chile and South Africa, there was no significant difference in the average mathematics scores between the two assessment periods.

Figure 3.2: Change in mathematics performance from TIMSS 1999 to TIMSS 2003, by country



Gender analysis

Participation rates

In most countries there was an almost equal participation between girls and boys, with rates located between 48–52 per cent. In South Africa, the TIMSS sample was 51 per cent girls and 49 per cent boys. Table 3.2 indicates the countries where the difference between girl and boy participation rates was 6 per cent or more.

Table 3.2: Countries where the difference in Grade 8 participation rates between girls and boys was 6 per cent or more

Girl participation > boy participation		Boy participation > girl participation	
Philippines	(by 16%)	Iran, Islamic Rep of	(by 20%)
Lebanon	(14%)	Saudi Arabia	(14%)
Palestinian Nat'l Auth	(10%)	Ghana	(10%)
Belgium	(8%)	Egypt	(8%)
Armenia	(6%)		
Tunisia	(6%)		

Performance by gender

Figure 3.3 presents the distribution of average mathematics achievement by gender. The international mathematics average score for girls (M = 467, SE = 0.6) and boys (M = 466, SE = 0.6) is not significantly different. In South Africa, the girls had a mathematics average scale score of 262 (SE = 6.2) and the boys had an average scale score of 264 (SE = 6.4). The difference is not statistically significant. There was also no significant gender difference in mathematics scale scores in TIMSS 1999.

There were 27 countries where the mathematics average scores were not significantly different between boys and girls, while in 18 countries there was a significant difference (see Table 3.3). Figure 3.3 also illustrates the average mathematics scores for girls and boys, as well as the difference. The horizontal bar for each country in Figure 3.3 shows the level of 'difference' between girls and boys.

Table 3.3: Countries where there was a significant difference between the average mathematics scale scores of girls and boys

Girls score statistically > boys	Boys score statistically > girls
Serbia	United States
Macedonia	Italy
Armenia	Hungary
Moldova	Lebanon
Singapore	Belgium (Flemish)
Philippines	Morocco
Cyprus	Chile
Jordan	Ghana
Bahrain	Tunisia

Figure 3.3: Average mathematics achievement by gender

Countries	Girls		Boys		Difference (absolute value)
	Percent of students	Average scale score	Percent of students	Average scale score	
Slovak Republic	48 (1.3)	508 (3.4)	52 (1.3)	508 (4.0)	0 (3.5)
Sweden	51 (0.9)	499 (3.0)	49 (0.9)	499 (2.7)	1 (2.2)
Indonesia	50 (0.7)	411 (4.9)	50 (0.7)	410 (5.3)	1 (3.0)
Egypt	46 (2.7)	407 (4.4)	54 (2.7)	406 (5.0)	1 (6.4)
Bulgaria	48 (1.3)	476 (5.5)	52 (1.3)	477 (4.3)	1 (4.7)
International avg.	50 (0.2)	467 (0.6)	50 (0.2)	466 (0.6)	1 (0.6)
Hong Kong, SAR	50 (2.4)	587 (3.8)	50 (2.4)	585 (4.6)	2 (5.1)
Estonia	50 (1.0)	532 (3.4)	50 (1.0)	530 (3.3)	2 (3.0)
New Zealand	52 (1.7)	495 (4.8)	48 (1.7)	493 (7.0)	3 (5.7)
Japan	49 (1.2)	569 (4.0)	51 (1.2)	571 (3.6)	3 (6.4)
South Africa	51 (0.9)	262 (6.2)	49 (0.9)	264 (6.4)	3 (5.8)
Norway	50 (0.8)	463 (2.7)	50 (0.8)	460 (3.0)	3 (2.8)
Russian Federation	49 (1.2)	510 (3.5)	51 (1.2)	507 (4.4)	3 (2.8)
Slovenia	50 (0.9)	495 (2.6)	50 (0.9)	491 (2.6)	3 (2.8)
Botswana	51 (0.7)	368 (2.6)	49 (0.7)	365 (2.9)	3 (1.8)
Romania	52 (0.9)	477 (5.1)	48 (0.9)	473 (5.0)	4 (3.3)
Lithuania	50 (0.9)	503 (2.9)	50 (0.9)	499 (3.0)	5 (2.9)
Scotland	50 (1.3)	500 (4.3)	50 (1.3)	495 (3.8)	5 (3.5)
Korea, Rep. of	48 (2.8)	586 (2.7)	52 (2.8)	592 (2.6)	5 (3.1)
Latvia	49 (0.8)	511 (3.3)	51 (0.8)	506 (3.7)	6 (2.9)
United States	52 (0.7)	502 (3.4)	48 (0.7)	507 (3.5)	6 (1.9)
Italy	50 (0.9)	481 (3.0)	50 (0.9)	486 (3.9)	6 (2.8)
Netherlands	49 (1.2)	533 (4.1)	51 (1.2)	540 (4.5)	7 (3.6)
Serbia	49 (0.8)	480 (2.9)	51 (0.8)	473 (2.9)	7 (2.8)
Chinese Taipei	48 (1.0)	589 (4.9)	52 (1.0)	582 (5.2)	7 (4.2)
Hungary	50 (1.0)	526 (3.7)	50 (1.0)	533 (3.5)	7 (3.2)
Malaysia	50 (1.8)	512 (4.7)	50 (1.8)	505 (4.5)	8 (4.2)
Israel	52 (1.6)	492 (3.3)	48 (1.6)	500 (4.5)	8 (4.0)
Palestinian Nat'l Auth.	55 (2.4)	394 (3.9)	45 (2.4)	386 (4.7)	8 (5.9)
Macedonia, Rep. of	49 (0.9)	439 (4.0)	51 (0.9)	431 (3.9)	9 (3.5)
Iran, Islamic Rep. of	40 (4.1)	417 (4.3)	60 (4.1)	408 (4.2)	9 (7.2)
Lebanon	57 (1.8)	429 (3.6)	43 (1.8)	439 (3.9)	10 (4.0)
Armenia	53 (0.7)	483 (3.3)	47 (0.7)	473 (3.4)	10 (3.0)
Moldova, Rep. of	51 (0.8)	465 (4.1)	49 (0.8)	455 (4.8)	10 (3.5)
Singapore	49 (0.8)	611 (3.3)	51 (0.8)	601 (4.3)	10 (2.9)
Saudi Arabia	43 (2.3)	326 (7.9)	57 (2.3)	336 (5.5)	10 (9.7)
Belgium (Flemish)	54 (2.1)	532 (3.5)	46 (2.1)	542 (3.8)	11 (4.8)
Morocco	50 (1.8)	381 (2.8)	50 (1.8)	393 (3.0)	12 (3.1)
Australia	51 (2.2)	499 (5.8)	49 (2.2)	511 (5.8)	13 (7.0)
Philippines	58 (0.9)	383 (5.2)	42 (0.9)	370 (5.8)	13 (3.4)
Chile	48 (1.6)	379 (3.5)	52 (1.6)	394 (4.3)	15 (4.5)
Cyprus	49 (0.6)	467 (1.9)	51 (0.6)	452 (2.3)	16 (2.7)
Ghana	45 (0.9)	266 (5.1)	55 (0.9)	283 (4.9)	17 (3.1)
Tunisia	53 (0.7)	399 (2.6)	47 (0.7)	423 (2.2)	24 (1.9)
Jordan	49 (1.7)	438 (4.6)	51 (1.7)	411 (5.8)	27 (6.8)
Bahrain	50 (0.4)	417 (2.4)	50 (0.4)	385 (2.4)	33 (3.3)
England	50 (2.4)	499 (5.3)	50 (2.4)	498 (5.8)	0 (6.0)
Benchmarking participants					
Basque Country, Spain	49 (1.7)	490 (2.5)	51 (1.7)	484 (3.7)	6 (3.1)
Indiana State, US	49 (1.2)	502 (5.1)	51 (1.2)	514 (5.8)	12 (3.4)
Ontario Province, Can.	51 (0.9)	520 (3.4)	49 (0.9)	522 (3.4)	2 (2.8)
Quebec Province, Can.	50 (1.6)	540 (3.7)	50 (1.6)	546 (3.3)	7 (3.3)

Notes:
Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year.
Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.
■ Gender difference statistically significant.
□ Gender difference not statistically significant.

Performance at international benchmarks

TIMSS identified four benchmark scores on the achievement scale to describe what learners know, and can do, in mathematics. Selected to represent the range of performance shown by learners internationally, TIMSS identified four points on the scale for use as international benchmarks. The four benchmarks were defined as: the Advanced International Benchmark (AIB), set at 625 and above; the High International Benchmark (HIB), set between 550 and 625; the Intermediate International Benchmark (IIB), set between 475 and 550; and the Low International Benchmark (LIB), set between 400 and 475. The descriptions of the levels are cumulative, so that a learner who has reached the higher benchmarks can demonstrate the knowledge and skills achieved at the lower levels (see Table 3.4).

Table 3.4: Descriptions of TIMSS 2003 international benchmarks for mathematics

Low (400)	Intermediate (475)	High (550)	Advanced (625)
Learners have some basic mathematical knowledge. Learners can: • do basic computations with whole numbers without a calculator; • select the two-place decimal closest to a whole number; • multiply two-place decimal numbers by three-place decimal numbers with calculators available; and • recognise some basic terminology and read information from a line on a graph.	Learners can apply basic mathematical knowledge in straightforward situations. Learners can: • add, subtract or multiply to solve one-step word problems involving whole numbers and decimals; • identify representations of common fractions and relative sizes of fractions; • understand simple algebraic relationships and solve linear equations with one variable; • demonstrate an understanding of properties of triangles and basic geometric concepts, including symmetry and rotation; and • recognise basic notions of probability. They can read and interpret graphs, tables, maps and scales.	Learners can apply their understanding and knowledge in a wide variety of relatively complex situations. Learners can: • order, relate, and compute with fractions and decimals to solve word problems, operate with negative integers, and solve multi-step word problems involving proportions with whole numbers; • solve simple algebraic problems, including evaluating expressions, solving simultaneous linear equations, and using a formula to determine the value of a variable; • find areas and volumes of simple geometric shapes and use knowledge of geometric properties to solve problems; and • solve probability problems and interpret data in a variety of graphs and tables.	Learners can organise information, make generalisations, solve non-routine problems, and draw and justify conclusions from the data. Learners can: • compute per cent change and apply their knowledge of numeric and algebraic concepts and relationships to solve problems; • solve simultaneous linear equations and model simple situations algebraically; • apply their knowledge of measurement and geometry in complex problem situations; and • interpret data from a variety of tables and graphs, including interpolation and extrapolation.

A scale-anchoring technique was used to develop descriptions of achievement for the TIMSS 2003 benchmarks. Scale anchoring describes learners' performance at different points on the achievement scale. The scale-anchoring technique involved an empirical component (in which items that discriminate between successive points on the scale were identified), and a judgemental component (in which experts in mathematics examined item content and used this to generalise learners' knowledge and understanding). In the scale-anchoring technique, results of all learners were pooled, so that the benchmark descriptions refer to all learners achieving at *that* level.

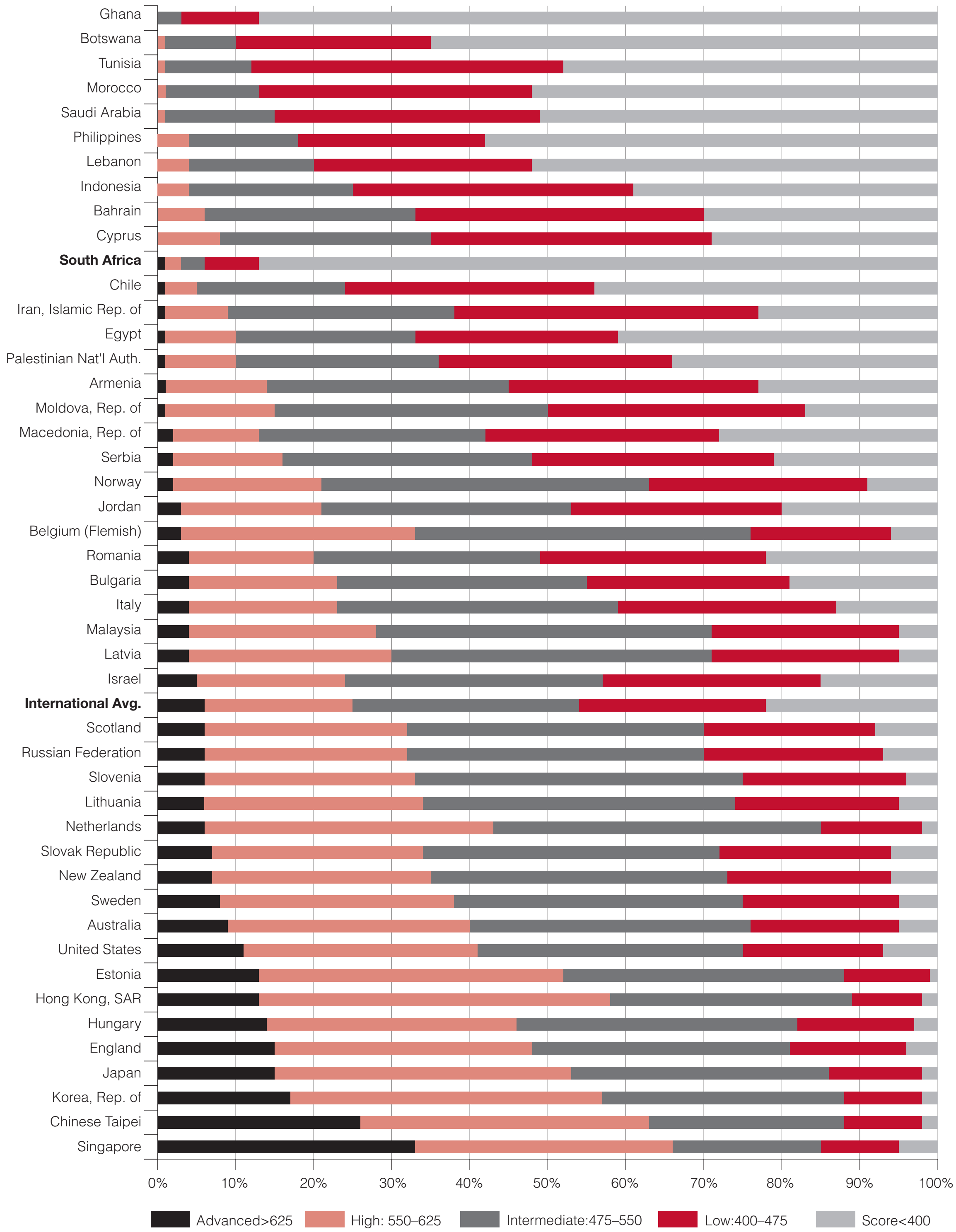
Figure 3.4 indicates how the different countries performed in respect of reaching the different international benchmarks in mathematics. The chart is arranged in rank order of performance at the AIB. While the chart is organised to draw particular attention to the percentage of high-achieving learners in each country, it also conveys information about middle and low performers.

The profile of performance in each of the countries varied widely. Singapore had 99 per cent of its learners achieve a score above the LIB (that is, scored higher than 400). Of these, 44 per cent of Singaporean learners performed at above the AIB (that is, scored higher than 625). The Netherlands had 97 per cent of its learners perform above the LIB – of these, 10 per cent performed at the AIB. Norway had 81 per cent of its learners achieving a score above the LIB, and under 0.5 per cent had scores above the AIB (that is, higher than 625).

South Africa had 10 per cent of its learners achieving a score higher than 400. Of these, 0.3 per cent of learners scored above the AIB level; 1.3 per cent scored at the HIB level; 3.2 per cent scored at the IIB level; and 5.3 per cent scored at the LIB level. These scores are cumulative, indicating that 90 per cent of South African learners scored lower than 400 scaled points. In Botswana, 32 per cent of the learners achieved a score higher than 400, and, in Ghana, 9 per cent of the learners scored higher than 400. South Africa and Ghana have the highest percentage of learners with a score lower than 400.

The mathematics score profile for South Africa indicates that there are very few high-performing mathematics learners at Grade 8. The implication of this is that there would be very few learners graduating from the school system with results in mathematics good enough to permit access to tertiary studies in the science or engineering fields. South Africa has committed itself to a science and technology pathway for the development of the individual and the social and economic development of the country. In order to achieve those goals, the country would have to achieve higher performance in mathematics at the lower levels of the schooling system.

Figure 3.4: Percentage of learners reaching the different benchmarks for mathematics in TIMSS 2003 by country



Examples of performance at different benchmarks

The following section provides examples of items from the TIMSS tests, classified at the different benchmarks. These examples provide an indication of the skills and abilities that the learner at each level could demonstrate. Each item is described and accompanied by the percentage correct for South Africa; for the five top performing countries; for the few lower-performing countries; and the international average percentage.

Performance at the Low International Benchmark (400)

Learners who reached this benchmark on TIMSS had some basic mathematical knowledge.

Which of these numbers is closest to 10?

- (A) 0.10
- (B) 9.99 (●)
- (C) 10.10
- (D) 10.90

Content area: number	Performance of selected countries		
Selects two-place decimal closest to a given whole number. Internationally, about 75 per cent of learners scored correctly on this item. In South Africa, 30 per cent of learners answered this item correctly.	Netherlands	97	(1.0)
	Sweden	96	(1.1)
	Estonia	96	(1.2)
	Singapore	95	(1.1)
	Lithuania	95	(1.0)
	International average	77	(0.3)
	Egypt	48	(2.5)
	Philippines	42	(2.8)
	Botswana	40	(2.6)
	Saudi Arabia	35	(2.6)
	South Africa	30	(2.7)
	Ghana	24	(2.4)

Performance at the Intermediate International Benchmark (475)

Learners who reached this benchmark could apply basic mathematical knowledge in straightforward situations.

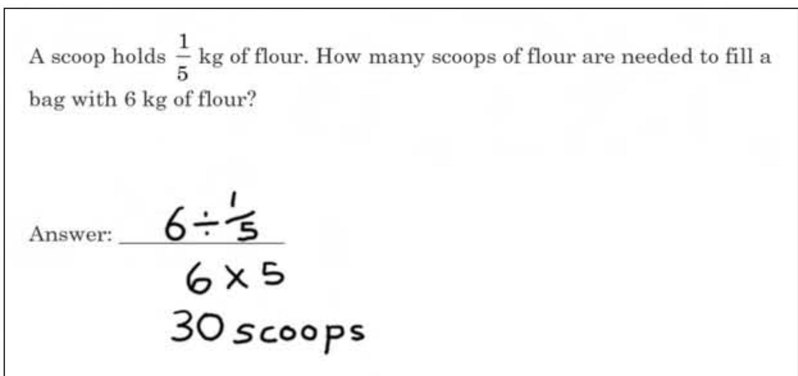
Alice ran a race in 49.86 seconds. Betty ran the same race in 52.30 seconds.
How much longer did it take Betty to run the race than Alice?

- (A) 2.44 seconds (●)
- (B) 2.54 seconds
- (C) 3.56 seconds
- (D) 3.76 seconds

Content area: number	Performance of selected countries	
Learners are expected to solve a word problem involving subtraction of a two-decimal number from another. Internationally, 61% of the learners scored this problem correctly. In South Africa, 29% of the learners scored correctly.	Singapore	88 (1.0)
	Korea, Rep. of	87 (1.1)
	Malaysia	81 (1.4)
	Netherlands	81 (2.0)
	Botswana	61 (1.7)
	International average	61 (0.3)
	Chile	42 (1.8)
	Palestinian Nat'l Auth.	37 (1.7)
	Ghana	32 (2.0)
	South Africa	29 (1.8)
	Saudi Arabia	19 (2.3)

Performance at the High International Benchmark (550)

Learners who reached this benchmark could apply their understanding and knowledge in a wide variety of relatively complex situations.


A scoop holds $\frac{1}{5}$ kg of flour. How many scoops of flour are needed to fill a bag with 6 kg of flour?

Answer: $6 \div \frac{1}{5}$

6×5

30 scoops

Content area: number	Performance of selected countries	
This is an example of a constructed-response question. Learners have to solve a one-step word problem involving division of a whole number by a unit fraction. The international average indicates that 38% of all learners answered correctly and in South Africa, 7% answered correctly.	Singapore	79 (1.9)
	Hong Kong, SAR	76 (1.8)
	Chinese Taipei	75 (1.9)
	Netherlands	74 (2.1)
	Korea, Rep. of	68 (1.5)
	International average	38 (0.3)
	Botswana	11 (1.1)
	Palestinian Nat'l Auth.	10 (1.2)
	Morocco	8 (1.5)
	South Africa	7 (1.3)
	Saudi Arabia	7 (1.9)
	Ghana	6 (1.0)

Performance at the Advanced International Benchmark (625)

Learners who reached this benchmark could organise information, make generalisations, solve non-routine problems, and draw and justify conclusions from data.

The three figures below are divided into small congruent triangles.

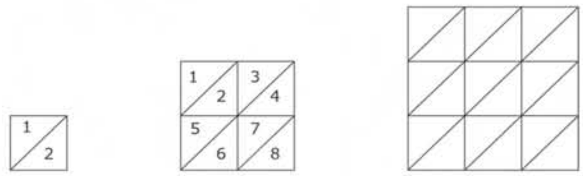


Figure 1 Figure 2 Figure 3

A. Complete the table below. First, fill in how many small triangles make up Figure 3. Then, find the number of small triangles that would be needed for the 4th figure if the sequence of figures is extended.

Figure	Number of Small Triangles
1	2
2	8
3	18
4	32

B. The sequence of figures is extended to the 7th figure. How many small triangles would be needed for Figure 7?

Answer: 98

$7^2 \times 2$
49×2

C. The sequence of figures is extended to the 50th figure. Explain a way to find the number of small triangles in the 50th figure that does not involve drawing it and counting the number of triangles.

$50^2 \times 2$
2500×2
5000

Content area: algebra	Performance of selected countries	
This is an example of a constructed-response question. Generalising from the first several terms of a sequence growing in two dimensions, explains a way to find a specified term e.g. the 50th. The international average was 14% and 1% of South African learners scored correctly.	Chinese Taipei	49 (2.0)
	Korea, Rep. of	48 (1.8)
	Hong Kong, SAR	45 (2.0)
	Singapore	44 (2.0)
	Japan	44 (2.1)
	International average	14 (0.2)
	Botswana	2 (0.5)
	South Africa	1 (0.5)
	Tunisia	1 (0.3)
	Ghana	1 (0.3)
	Saudi Arabia	0 (0.1)

Summary

There were 50 participating countries in TIMSS 2003. The five highest performing countries in mathematics were Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei and Japan. The five lowest performing countries were the Philippines, Botswana, Saudi Arabia, Ghana and South Africa. The mathematics average scale score for South African Grade 8 learners was the lowest, at 264 (SE = 5.5), and this was significantly lower than the international average score (M = 467, SE = 0.5). The South African scores displayed the widest range when compared against any other country.

In most countries there were equitable participation rates, with participation of girls and boys varying from 48 to 52 per cent. The international mathematics average score for girls (M = 467, SE = 0.6) and for boys (M = 466, SE = 0.6) is not significantly different. In South Africa, the girls had an average scale score of 262 (SE = 6.2) and the boys had an average scale score of 264 (SE = 6.4). The difference is not statistically significant. In nine participating countries the mathematics scores of boys were statistically higher than those of the girls; and nine participating countries revealed the girls' scores to be statistically higher than the boys.

South Africa had 10 per cent of the population achieve a score higher than the LIB (that is, a score higher than 400). This means that 90 per cent of the learners scored less than 400 scale points. South Africa and Ghana were the weakest performers, with the highest number of learners scoring below the LIB.

South African science achievement in an international context

This chapter summarises achievement of the TIMSS 2003 science assessment for each of the participating countries and contextualises the performance of South African learners in relation to the 50 study participants. The overview, as presented here, is based on trends in the TIMSS 2003 report (Martin, Mullis, Gonzalez & Chrostowski 2004).[1] In addition to presenting the international comparative results, a comparison of the results for the participating group of African countries is given. There is also a discussion of the performance trend from 1999 to 2003, an examination of performance as it relates to gender, and an analysis of performance at the different performance benchmarks.

Science achievement of participating countries in TIMSS 2003

Figure 4.1 presents the average science achievement distribution for each of the participating countries. TIMSS used IRT methods to calculate the achievement scores. A scale of 800 points and a standard deviation of 100 points was used. The international average was computed by averaging the mean scores of each of the participating countries. In Figure 4.1, average scores are arranged from the highest to the lowest. The results show substantial differences in science achievement between the highest and lowest performing countries, from an average of 578 for Singapore to 244 for South Africa. Twenty-eight countries achieved average science scores significantly higher than the international average and 18 countries achieved scores significantly lower than the international average. The five highest performing countries were: Singapore, Chinese Taipei, Republic of Korea, Hong Kong (SAR) and Estonia. The five lowest performing countries were: Lebanon, Philippines, Botswana, Ghana and South Africa.

Figure 4.1 illustrates the broad range of achievement both within and across the countries assessed. Achievement for each country is shown at the 25th and 75th percentiles, as well as the 5th and 95th percentiles. Each percentile point indicates the percentage of learners performing below and above that point on the scale. For example, 25 per cent of the learners in each country performed below the 25th percentile and 75 per cent performed above the 25th percentile. The range between the 25th and 75th percentiles represents performance by the middle half of the learners. Performance at the 5th and 95th percentile represents the extremes in lower and higher achievement. The range of performance between these two score points, which included 90 per cent of the population, is approximately 200 to 300 points in most countries. The dark boxes at the midpoints of the distributions show the 95 per cent confidence intervals around the average achievement in each country.

As shown in Figure 4.1, the average scale score for South African Grade 8 learners was the lowest at 244 (SE = 6.7), and this was significantly lower than the international average scale score of 474 (SE = 0.6). In comparing individual countries, the South African average was not statistically different from that of Ghana, but it was significantly lower than those of the remaining participating countries.

1 This report is available at: http://www.timss/bc/edu.

Apart from the substantial difference in science achievement scores between the highest performing country (Singapore) and South Africa, it is interesting to observe the variation of scores within countries. This variation was examined using the range of scores between the 5th and 95th percentiles. A striking feature of Figure 4.1 is the fact that Singapore's average performance exceeds South African performance at the 95th percentile – this means that only the most proficient learners in South Africa approached the average proficiency of Singaporean learners. Secondly, of all the countries participating, South Africa had the widest range of scores between the 5th and 95th percentiles – a difference of approximately 450 points. This suggests that South Africa has some learners who perform very poorly and some who perform very well.

When interpreting the comparative results presented in this report, it is important to remember that each country's result is an estimate of the total population value, inferred from the result obtained from the sample of learners tested. Because it is an estimate, it is subject to some potential level of error. The variability of the average score is given by the SE of the average, presented in the tables. We can say with 95 per cent confidence that the true population average lies within about 2 standard errors of the sample average. Standard errors are influenced by the size of the sample, the design of the sample and the variation scores in the sample.

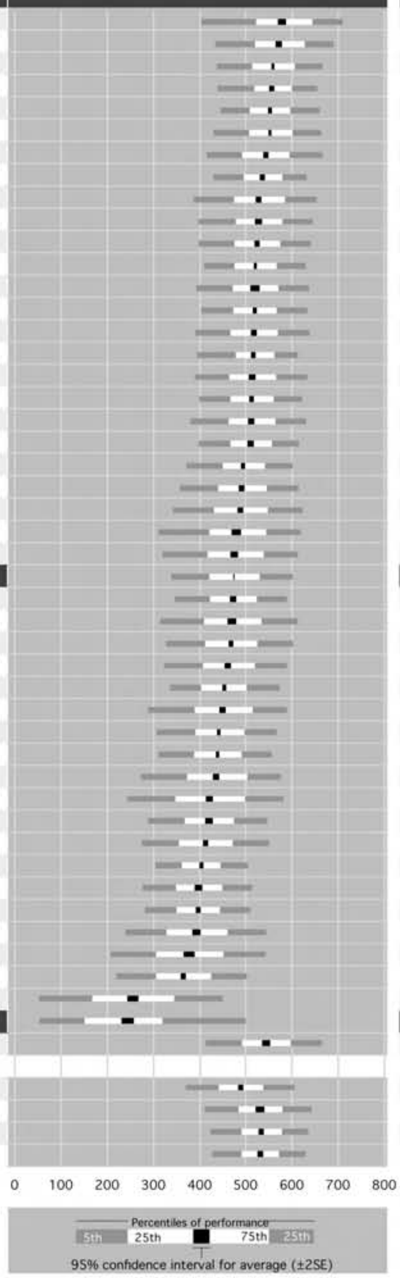
To illustrate the use of standard errors with the average, we can look at South Africa's score. South Africa had an average score of 244 with a standard error of 6.7. This means that the average score for the population of Grade 8 learners in South Africa lies between 237 and 251.

To help interpret scores of the different countries, Figure 4.1 also includes the years of formal schooling and the average age of the learners assessed in each of the participating countries. Most countries assessed the learners at the end of their eighth year of schooling. The international average age of the learners assessed is 14.5 years. Learners in some Eastern European countries start school later and so tended to be older. Learners were older in many African countries where they may have started school later or had their schooling interrupted.

Not all countries have similar socio-economic conditions. Figure 4.1 includes the value of the HDI for each of the participating countries. This index, calculated by UNDP has a minimum value of 0 and a maximum value of 1. The index is a summary measure of human development in a country and is constructed from three dimensions: values for life expectancy at birth, knowledge – constructed from the adult literacy rate and combined primary, secondary and tertiary gross enrolment rates – and standard of living, as measured by the per capita GDP. TIMSS countries with an HDI value greater than 0.9 included Australia, Belgium, England, Israel, Japan, Norway and the United States. The HDI for South Africa was 0.684. Other TIMSS countries with an HDI less than 0.7 were Indonesia (0.682), Botswana (0.614), Morocco (0.606) and Ghana (0.567).

Figure 4.1: Distribution of science achievement

Countries	Years of schooling*	Average age	Science achievement distribution	Average scale score		Human Development Index**
Singapore	8	14.3		578 (4.3)	h	0.884
Chinese Taipei	8	14.2		571 (3.5)	h	–
Korea, Rep. of	8	14.6		558 (1.6)	h	0.879
Hong Kong, SAR	8	14.4		556 (3.0)	h	0.889
Estonia	8	15.2		552 (2.5)	h	0.833
Japan	8	14.4		552 (1.7)	h	0.932
Hungary	8	14.5		543 (2.8)	h	0.837
Netherlands	8	14.3		536 (3.1)	h	0.938
United States	8	14.2		527 (3.1)	h	0.937
Australia	8 or 9	13.9		527 (3.8)	h	0.939
Sweden	8	14.9		524 (2.7)	h	0.941
Slovenia	7 or 8	13.8		520 (1.8)	h	0.881
New Zealand	8.5 - 9.5	14.1		520 (5.0)	h	0.917
Lithuania	8	14.9		519 (2.1)	h	0.824
Slovak Republic	8	14.3		517 (3.2)	h	0.836
Belgium (Flemish)	8	14.1		516 (2.5)	h	0.937
Russian Federation	7 or 8	14.2		514 (3.7)	h	0.779
Latvia	8	15.0		512 (2.6)	h	0.811
Scotland	9	13.7		512 (3.4)	h	0.930
Malaysia	8	14.3		510 (3.7)	h	0.790
Norway	7	13.8		494 (2.2)	h	0.944
Italy	8	13.9		491 (3.1)	h	0.916
Israel	8	14.0		488 (3.1)	h	0.905
Bulgaria	8	14.9		479 (5.2)		0.795
Jordan	8	13.9		475 (3.8)		0.743
International avg.	8	14.5		474 (0.6)		–
Moldova, Rep. of	8	14.9		472 (3.4)		0.700
Romania	8	15.0		470 (4.9)		0.773
Serbia	8	14.9		468 (2.5)	l	–
Armenia	8	14.9		461 (3.5)	l	0.729
Iran, Islamic Rep. of	8	14.4		453 (2.3)	l	0.719
Macedonia, Rep. of	8	14.6		449 (3.6)	l	0.784
Cyprus	8	13.8		441 (2.0)	l	0.891
Bahrain	8	14.1		438 (1.8)	l	0.839
Palestinian Nat'l Auth	8	14.1		435 (3.2)	l	0.731
Egypt	8	14.4		421 (3.9)	l	0.648
Indonesia	8	14.5		420 (4.1)	l	0.682
Chile	8	14.2		413 (2.9)	l	0.831
Tunisia	8	14.8		404 (2.1)	l	0.740
Saudi Arabia	8	14.1		398 (4.0)	l	0.769
Morocco	8	15.2		396 (2.5)	l	0.606
Lebanon	8	14.6		393 (4.3)	l	0.752
Philippines	8	14.8		377 (5.8)	l	0.751
Botswana	8	15.1		365 (2.8)	l	0.614
Ghana	8	15.5		255 (5.9)	l	0.567
South Africa	8	15.1		244 (6.7)	l	0.684
England	9	14.3		544 (4.1)	h	0.930
Benchmarking Participants						
Basque Country, Spa	8	14.1		489 (2.7)	h	–
Indiana State, US	8	14.5		531 (4.8)	h	–
Ontario Province, Car	8	13.8		533 (2.7)	h	–
Quebec Province, Car	8	14.2		531 (3.0)	h	–



Notes:

* Represents years of schooling counting from the first year of ISCED Level 1.

** Taken from United Nations Development Program's *Human Development Report 2003*: 237–240.

Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year.

Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

A dash (–) indicates comparable data are not available.

h Country average significantly higher than international average.

l Country average significantly lower than international average.

South Africa in relation to other African countries

The TIMSS 2003 study included six African countries. These were: Botswana, Egypt, Ghana, Morocco, Tunisia and South Africa. South Africa, Morocco and Tunisia had participated in TIMSS 1999, while the other three made their debut in TIMSS 2003. A comparison of these countries is sensible because other variables, together with science achievement scores, can provide a more contextualised perspective. Table 4.1 provides information on key indicators in these countries.

Table 4.1: Scale scores and key indicators of African country participants in TIMSS 2003

	Average science scale score (SE)	Population (millions)	Life expectancy (years)	Net enrolment (primary)	Net enrolment (secondary)	GNI per capita in US$
Egypt	421 (3.9)	66.4	69	90	78	1 470
Tunisia	404 (2.1)	9.8	73	97	68	1 990
Morocco	396 (2.5)	29.6	68	88	31	1 170
Botswana	365 (2.8)	1.7	38	81	55	3 010
Ghana	255 (5.9)	20.3	55	60	30	270
South Africa	244 (6.7)	45.3	46	90	62	2 500

Sources: UNDP 2003; Martin, Mullis, Gonzales et al 2004

Table 4.1 illustrates the differences, in the six African countries, on indicators which could influence education outcomes. For example, the population of Botswana is 1.7 million, whereas the size of the South African education system is 12 million; in Ghana, 30 per cent of the secondary learners of the age cohort who are supposed to be in secondary school are in school, whereas in South Africa the net enrolment rate in secondary schools is 62 per cent. South Africa has one of the highest GNIs (in US dollars) per capita of the group, yet has the lowest average mean score in science. Table 4.1 suggests that the explanations for learner achievement cannot be provided by a single indicator – it is the interaction of a number of variables that produces a particular outcome.

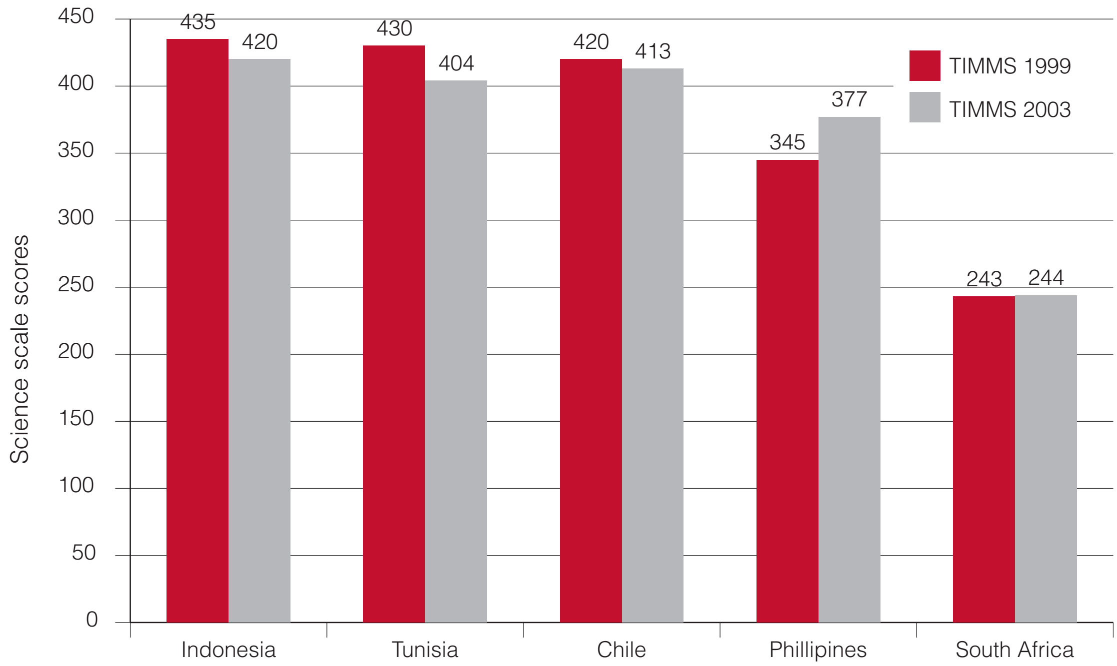
Changes in science achievement between TIMSS 1999 and TIMSS 2003

There are some countries that participated in both TIMSS 1999 and TIMSS 2003. For these countries it was possible to track the changes in performance over these two periods of time. The international science average score in TIMSS 1999 was 488 (SE = 0.7) and in TIMSS 2003 it was 474 (SE = 0.6).[2]

Figure 4.2 presents national comparisons for the two assessment periods for the five lowest performing countries. Scores for Indonesia and Tunisia decreased significantly from 1999 to 2003. In the Philippines there was a significant increase in the average science score. The South African average science score for TIMSS 2003 was one point higher than for TIMSS 1999. This difference is not significant.

2 One cannot compare the international averages because different countries participated in different years.

Figure 4.2: Change in science performance from TIMSS 1999 to TIMSS 2003, by country



Gender analysis

Participation rates

In most countries there was an almost equal participation between boys and girls, with rates located between 48–52 per cent. In South Africa, the TIMSS sample was 51 per cent of girls and 49 per cent boys. Table 4.2 indicates the countries where the difference between girl and boy participation rates was 6 per cent or more.

Table 4.2: Countries where the difference in Grade 8 participation rates between girls and boys was 6 per cent or more

Girl participation > boy participation		Boy participation > girl participation	
Philippines	(by 16%)	Iran, Islamic Rep of	(by 20%)
Lebanon	(14%)	Saudi Arabia	(14%)
Palestinian Nat'l Auth	(10%)	Ghana	(10%)
Belgium	(8%)	Egypt	(8%)
Armenia	(6%)		
Tunisia	(6%)		

Performance by gender

Figure 4.3 presents the distribution of average science achievement scores by gender. The international science average scale score for girls is 471 (SE = 0.7) and the average scale score for boys is 477 (SE = 0.7). The difference of 6 (SE = 0.6) is statistically significant, with boys outperforming girls. For South Africa, the girls average scale score is 242 (SE = 7.2) and the boys 244 (SE = 7.7). The difference of 2 points is not statistically significant.

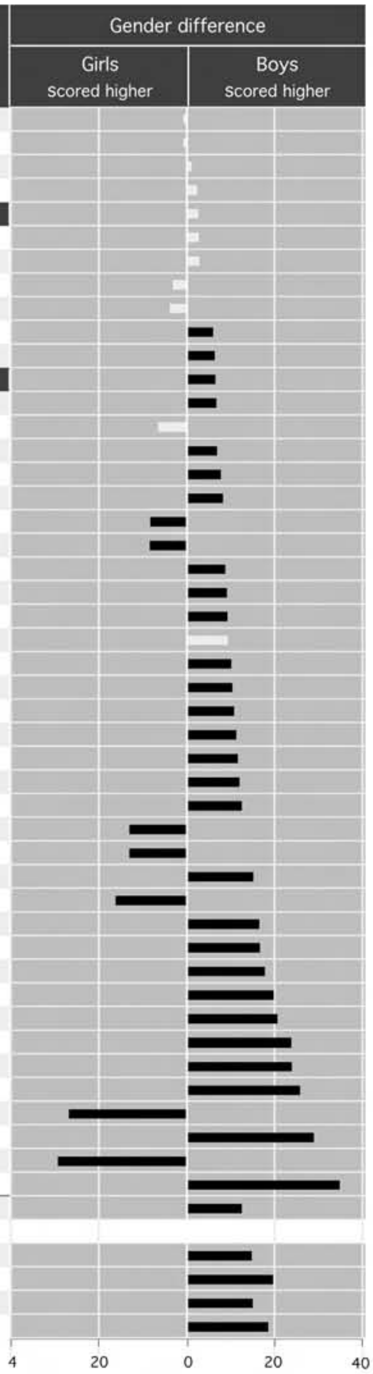
There were 11 countries where science average scores were not significantly different between boys and girls. In seven countries the science score of girls was significantly higher than that of the boys, and in 28 countries the boys science score was statistically higher than that of the girls. Table 4.3 lists the countries where there was a significant difference between the average scale scores of girls and boys. In addition, Figure 4.3 illustrates the average science scores for girls and boys, as well as the difference. The horizontal bar for each country in Figure 4.3 shows the level of 'difference' between girls and boys.

Table 4.3: Countries where there was a difference between the average science scale scores of girls and boys

No gender difference in performance	Girls score statistically > than boys	Boys score statistically > than girls	
Botswana	Armenia	Australia	Lithuania
Chinese Taipei	Bahrain	Belgium (Flemish)	Malaysia
Cyprus	Jordan	Bulgaria	Morocco
Egypt	Macedonia	Chile	Netherlands
Estonia	Moldova	England	Norway
Iran, Islamic Rep of	Palestinian Nat'l Auth.	Ghana	Romania
Lebanon	Saudi Arabia	Hong Kong, SAR	Russia Federation
New Zealand		Hungary	Serbia
Philippines		Indonesia	Scotland
Singapore		Israel	Slovak Republic
South Africa		Italy	Slovenia
		Japan	Sweden
		Korea, Rep. of	Tunisia
		Latvia	United States

Figure 4.3: Average science achievement by gender

Countries	Girls: Percent of students	Girls: Average scale score	Boys: Percent of students	Boys: Average scale score	Difference (absolute value)
Egypt	46 (2.7)	422 (4.8)	54 (2.7)	421 (5.5)	1 (6.8)
Iran, Islamic Rep. of	40 (4.1)	454 (3.9)	60 (4.1)	453 (3.7)	1 (6.1)
Chinese Taipei	48 (1.0)	571 (3.8)	52 (1.0)	572 (3.8)	1 (3.1)
Botswana	51 (0.7)	364 (3.2)	49 (0.7)	366 (3.4)	2 (3.3)
South Africa	51 (0.9)	242 (7.2)	49 (0.9)	244 (7.7)	2 (6.1)
Lebanon	57 (1.8)	392 (4.8)	43 (1.8)	395 (6.0)	3 (6.4)
Singapore	49 (0.8)	576 (4.0)	51 (0.8)	579 (5.0)	3 (3.1)
Estonia	50 (1.0)	554 (2.8)	50 (1.0)	551 (2.9)	3 (2.8)
Cyprus	49 (0.6)	443 (2.3)	51 (0.6)	440 (2.8)	4 (3.0)
Lithuania	50 (0.9)	516 (2.7)	50 (0.9)	522 (2.4)	6 (2.5)
Serbia	49 (0.8)	465 (2.9)	51 (0.8)	471 (2.6)	6 (2.5)
International avg.	50 (0.2)	471 (0.7)	50 (0.2)	477 (0.7)	6 (0.6)
Slovenia	50 (0.9)	517 (2.4)	50 (0.9)	524 (2.3)	7 (3.0)
Philippines	58 (0.9)	380 (5.9)	42 (0.9)	374 (6.4)	7 (4.1)
Latvia	49 (0.8)	509 (2.6)	51 (0.8)	516 (3.0)	7 (2.4)
Sweden	51 (0.9)	521 (3.2)	49 (0.9)	528 (2.7)	8 (2.5)
Norway	50 (0.8)	490 (2.2)	50 (0.8)	498 (3.0)	8 (2.9)
Macedonia, Rep. of	49 (0.9)	454 (3.7)	51 (0.9)	445 (4.2)	8 (3.3)
Moldova, Rep. of	51 (0.8)	477 (3.5)	49 (0.8)	468 (3.7)	8 (2.6)
Romania	52 (0.9)	465 (5.5)	48 (0.9)	474 (4.9)	9 (3.5)
Hong Kong, SAR	50 (2.4)	552 (3.4)	50 (2.4)	561 (3.8)	9 (3.9)
Japan	49 (1.2)	548 (3.0)	51 (1.2)	557 (2.7)	9 (4.5)
New Zealand	52 (1.7)	515 (4.8)	48 (1.7)	525 (6.7)	9 (5.7)
Malaysia	50 (1.8)	505 (4.3)	50 (1.8)	515 (4.0)	10 (4.0)
Italy	50 (0.9)	486 (2.7)	50 (0.9)	496 (3.8)	10 (2.5)
Russian Federation	49 (1.2)	508 (3.7)	51 (1.2)	519 (4.2)	11 (3.1)
Morocco	50 (1.8)	392 (3.2)	50 (1.8)	403 (3.8)	11 (4.6)
Indonesia	50 (0.7)	415 (3.9)	50 (0.7)	426 (4.6)	11 (2.7)
Scotland	50 (1.3)	506 (4.0)	50 (1.3)	517 (3.5)	12 (3.6)
Korea, Rep. of	48 (2.8)	552 (2.1)	52 (2.8)	564 (1.9)	12 (2.5)
Armenia	53 (0.7)	468 (4.0)	47 (0.7)	455 (3.4)	13 (2.8)
Palestinian Nat'l Au	55 (2.4)	441 (3.7)	45 (2.4)	428 (5.2)	13 (6.2)
Netherlands	49 (1.2)	528 (3.3)	51 (1.2)	543 (3.8)	15 (3.5)
Saudi Arabia	43 (2.3)	407 (6.2)	57 (2.3)	391 (5.4)	16 (8.2)
Bulgaria	48 (1.3)	470 (6.3)	52 (1.3)	487 (5.2)	16 (5.2)
United States	52 (0.7)	519 (3.2)	48 (0.7)	536 (3.4)	16 (2.1)
Slovak Republic	48 (1.3)	508 (3.8)	52 (1.3)	525 (3.4)	18 (3.1)
Israel	52 (1.6)	479 (3.2)	48 (1.6)	498 (4.1)	20 (4.2)
Australia	51 (2.2)	517 (4.6)	49 (2.2)	537 (4.6)	20 (5.6)
Belgium (Flemish)	54 (2.1)	505 (3.0)	46 (2.1)	528 (3.4)	24 (4.2)
Tunisia	53 (0.7)	392 (2.3)	47 (0.7)	416 (2.6)	24 (2.6)
Hungary	50 (1.0)	530 (3.4)	50 (1.0)	556 (3.0)	26 (3.0)
Jordan	49 (1.7)	489 (4.5)	51 (1.7)	462 (5.6)	27 (6.9)
Chile	48 (1.6)	398 (3.2)	52 (1.6)	427 (3.6)	29 (4.0)
Bahrain	50 (0.4)	453 (2.7)	50 (0.4)	423 (2.3)	29 (3.5)
Ghana	45 (0.9)	236 (6.4)	55 (0.9)	271 (6.5)	35 (4.7)
England	50 (2.4)	538 (4.7)	50 (2.4)	550 (5.1)	12 (5.3)
Benchmarking participants					
Basque Country, Sp	49 (1.7)	481 (3.0)	51 (1.7)	496 (3.3)	15 (3.6)
Indiana State, US	49 (1.2)	521 (4.7)	51 (1.2)	540 (5.3)	19 (3.1)
Ontario Province, C	51 (0.9)	526 (3.1)	49 (0.9)	540 (2.8)	15 (2.6)
Quebec Province, C	50 (1.6)	522 (3.7)	50 (1.6)	540 (3.2)	18 (3.1)



Notes:

Korea tested the same cohort of students as other countries, but later in 2003, at the beginning of the next school year.

Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

■ Gender difference statistically significant.

□ Gender difference not statistically significant.

Performance at international benchmarks

TIMSS identified four benchmarks on the achievement scale to describe what learners know, and can do, in science. Selected to represent the range of performance shown by learners internationally, TIMSS identified four points on the scale for use as international benchmarks. The four benchmarks were defined as: the Advanced International Benchmark (AIB), set at 625 and above; the High International Benchmark (HIB), set between 550 and 625; the Intermediate International Benchmark (IIB), set between 475 and 550; and the Low International Benchmark (LIB), set between 400 and 475. The descriptions of the levels are cumulative, so that a learner who has reached the higher benchmarks can demonstrate the knowledge and skills achieved at the lower levels (see Table 4.4).

Table 4.4: Descriptions of TIMSS 2003 international benchmarks for science

Low (400)	Intermediate (475)	High (550)	Advanced (625)
Learners recognise some basic facts from the life and physical sciences. Learners: • have some knowledge of the human body and heredity, and can demonstrate familiarity with everyday physical phenomena; and • can interpret some pictorial diagrams and apply knowledge of simple physical concepts to practical situations.	Learners can recognise and communicate basic scientific knowledge across a range of topics. Learners: • recognise some characteristics of the solar system, water cycle, animals, and human health; • are acquainted with some aspects of energy, force and motion, light reflection, and sound; • demonstrate elementary knowledge of human impact on and changes in the environment; and • can apply and briefly communicate knowledge, extract tabular information, extrapolate from data presented in a simple linear graph, and interpret pictorial diagrams.	Learners demonstrate conceptual understanding of some science cycles, systems, and principles. Learners: • have some understanding of Earth's processes and the solar system, biological systems, populations, reproduction and heredity, and the structure and function of organisms; • show some understanding of physical and chemical changes and the structure of matter; • solve some basic physics problems related to light, heat, electricity and magnetism, and they demonstrate basic knowledge of major environmental issues; • demonstrate some scientific inquiry skills; and • can combine information to draw conclusions; interpret information in diagrams, graphs and tables to solve problems; and provide short explanations conveying scientific knowledge and cause/effect relationships.	Learners demonstrate a grasp of some complex and abstract science concepts. Learners: • can apply knowledge of the solar system and of earth features, processes and conditions, and apply understanding of the complexity of living organisms and how they relate to their environment; • show understanding of electricity, thermal expansion and sound, as well as the structure of matter and physical and chemical properties and changes; • show understanding of environmental and resource issues; • understand some fundamentals of scientific investigation and can apply basic physical principles to solve some quantitative problems; and • can provide written explanations to communicate scientific knowledge.

A scale-anchoring technique was used to develop descriptions of achievement for the TIMSS 2003 benchmarks. Scale anchoring describes learners' performance at different points on the achievement scale. The scale-anchoring technique involved an empirical component; in which items that discriminate between successive points on the scale were identified, and a judgemental component; in which experts in science examined item content and used this to generalise learners' knowledge and understanding. In the scale-anchoring technique, results of all learners were pooled, so that the benchmark descriptions refer to all learners achieving at *that* level.

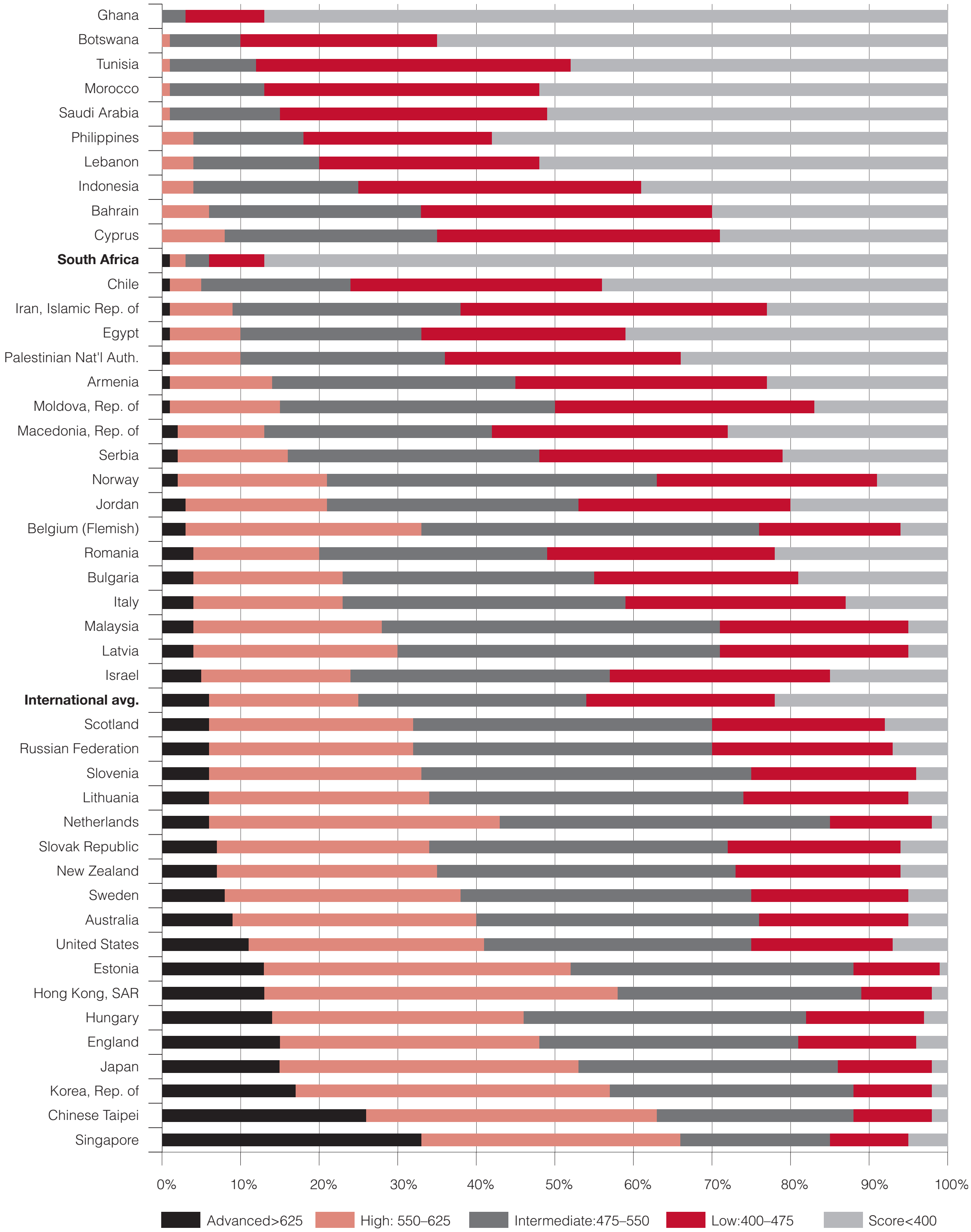
Figure 4.4 indicates how the different countries performed in respect of reaching the different international benchmarks in science. The chart is arranged in rank order of performance at the AIB. While the chart is organised to draw particular attention to the percentage of high-achieving learners in each country, it also conveys information about middle and low performers.

The profile of performance in each of the countries varied. Singapore had 33 per cent of its learners performing at the AIB level; 33 per cent performing at the HIB level; approximately 20 per cent performing at the IIB level; and 10 per cent performing at the LIB level. In Singapore, 95 per cent of learners achieved a score above the LIB (that is, higher than 400). The Netherlands displayed a slightly different learner profile, with 6 per cent of its learners performing at the AIB level; 37 per cent performing at the HIB level; 42 per cent at the IIB level; and 13 per cent at the LIB level. In the Netherlands, 98 per cent of learners achieved a score above the LIB (that is, higher than 400).

South Africa had 13 per cent of its learners achieving a score greater than 400. Of these, 1 per cent scored above the AIB level; 2 per cent scored at the HIB level; 3 per cent scored at the IIB level; and 7 per cent scored at the LIB level. These scores are cumulative. In Botswana, 35 per cent of the learners achieved a score higher than 400, and, in Ghana, 13 per cent of the learners achieved a score higher than 400.

It is worth noting South Africa's position (as shown in Figure 4.4). Unlike many countries at the bottom end of the scale, 1 per cent of South African learners achieved scores at the AIB level. Whereas all the other countries (except Ghana) at the bottom end of the scale had at least one-third of their learners reach the LIB level (that is, they scored 400), South Africa and Ghana had only 13 per cent of their learners reaching the scaled score of 400. This means that 87 per cent of South African and Ghanain learners scored below 400. This again illustrates the large variation in South African performance – with a few learners performing very well but the majority performing poorly.

Figure 4.4: Percentage of learners reaching the different benchmarks for science in TIMSS 2003, by country



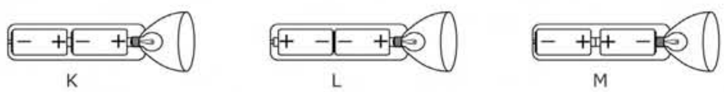
Examples of performance at different benchmarks

The following section provides examples of items from the TIMSS tests, classified at the different benchmarks. These examples provide an indication of the skills and abilities that the learner at each level could demonstrate. Each item is described and is accompanied by the percentage correct for South Africa; for the five top performing countries; the countries at the low-performing end of the spectrum; and the international average percentage.

Performance at the Low International Benchmark (400)

Learners who reached this benchmark on TIMSS had some knowledge and basic facts of life and physical sciences.

The diagrams show a flashlight and three ways to put batteries in it.



In order to make the flashlight work, which way must the batteries be placed?

- (A) Only as in K
- (B) Only as in L
- (C) Only as in M
- (D) None of these ways would work.

Content area: physics

In this item, learners were asked to identify the diagram depicting the correct arrangement of batteries in a flashlight or torch.

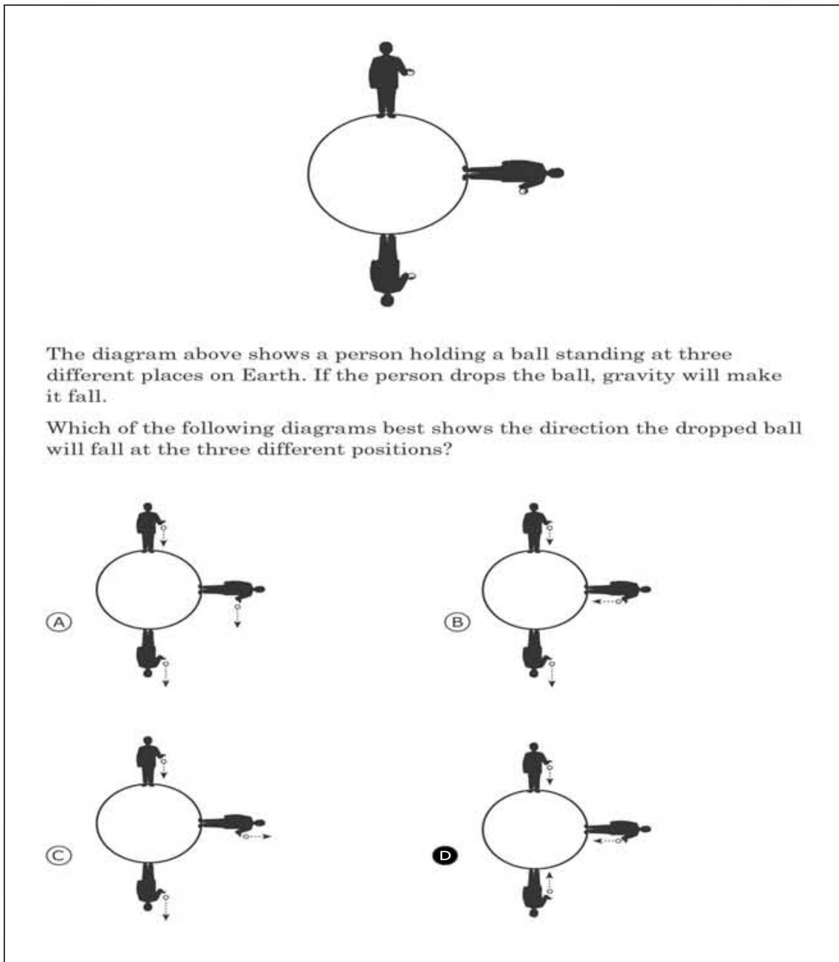
This was a simple item for most learners in the international study, with 85% of all learners scoring correctly on the item. South Africa had the lowest number of learners (at 52%) correctly answering this item.

Performance of selected countries

Singapore	97 (0.5)
Korea, Rep. of	93 (0.8)
Japan	93 (0.9)
Hong Kong, SAR	93 (0.9)
International average	85 (0.2)
Botswana	81 (1.3)
Morocco	81 (2.2)
Jordan	78 (1.9)
Saudi Arabia	78 (2.3)
Palestinian Nat'l Auth.	78 (1.8)
Philippines	77 (1.6)
Egypt	67 (2.1)
Tunisia	59 (1.9)
Ghana	55 (1.8)
South Africa	52 (1.7)

Performance at the Intermediate International Benchmark (475)

Learners who reached this benchmark could recognise and communicate basic scientific knowledge across a range of topics.



Content area: physics

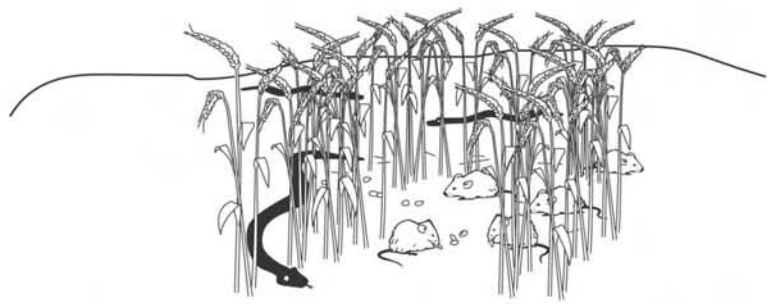
Learner uses knowledge of gravity to recognise that objects fall towards the centre of earth.

The international average was 70%, and 40% of South African learners correctly answered this question.

Performance of selected countries	
Japan	92 (1.2)
Estonia	91 (1.7)
Korea, Rep. of	90 (1.5)
Hungary	88 (2.1)
Sweden	87 (1.8)
International average	70 (0.4)
Botswana	61 (2.7)
Egypt	51 (2.3)
Tunisia	47 (2.5)
Ghana	43 (2.9)
South Africa	40 (2.1)
Morocco	6 (1.3)

Performance at the High International Benchmark (550)

Learners who reached this benchmark demonstrated conceptual understanding of some science cycles, systems and principles.



The diagram above shows a community consisting of mice, snakes and wheat plants.

What would happen to this community if people killed the snakes?

Because there are no snakes, we would get more mice. This would cause less wheat plants.

Content area: life sciences	Performance of selected countries	
Given that a community consists of mice, snakes and wheat plants, learners must explain what would happen to the mice and wheat plants if the snakes are killed. This is an example of a constructed-response question. Internationally, 33% of all learners answered correctly, and in South Africa 6% of learners answered correctly.	Singapore	78 (1.8)
	Malaysia	68 (2.1)
	Chinese Taipei	55 (2.0)
	Estonia	52 (2.3)
	Australia	50 (2.3)
	International average	33 (0.3)
	Morocco	16 (1.8)
	Philippines	16 (1.5)
	Lebanon	9 (1.6)
	Botswana	6 (1.1)
	South Africa	6 (1.1)
	Ghana	3 (0.6)

Performance at the Advanced International Benchmark (625)

Learners who reached this benchmark demonstrated a grasp of some complex and abstract science concepts.

The table shows some information about the planets Venus and Mercury.

	Average Surface Temperature (°C)	Atmospheric Composition	Mean Distance from the Sun (millions of km)	Time to Revolve Around the Sun (Number of Days)
Venus	470	Mostly Carbon Dioxide	108	225
Mercury	300	Trace amounts of gases	58	88

Which of the following best explains why the surface temperature of Venus is higher than that of Mercury?

Ⓐ There is less absorption of sunlight on Mercury because of the lack of atmospheric gases.

● B The high percentage of carbon dioxide in the atmosphere of Venus causes a greenhouse effect.

Ⓒ The longer time for Venus to revolve around the Sun allows it to absorb more heat from the Sun.

Ⓓ The Sun's rays are less direct on Mercury because it is closer to the Sun.

Content area: earth science

Given a table showing information about Venus and Mercury, the learner recognises that the higher average surface temperature on Venus is due to the greenhouse effect.

Internationally, just over one third of learners answered the question correctly and South Africa performed relatively well, with 23% of the learners answering correctly.

Performance of selected countries	
Korea, Rep. of	70 (1.9)
Hong Kong, SAR	69 (1.7)
Chinese Taipei	69 (1.6)
Singapore	60 (1.8)
International average	36 (0.3)
South Africa	23 (1.3)
Ghana	22 (1.7)
Tunisia	19 (1.3)
Saudi Arabia	18 (2.0)
Indonesia	16 (1.4)
Morocco	16 (1.8)
Macedonia, Rep. of	15 (1.7)
Armenia	15 (1.7)

Summary

There were 50 participating countries in TIMSS 2003. The five highest performing countries were Singapore, Chinese Taipei, Republic of Korea, Hong Kong (SAR) and Estonia. The five lowest performing countries were Lebanon, Philippines, Botswana, Ghana and South Africa. The science average scale score for South African Grade 8 learners was the lowest, at 244 (SE = 6.7), and this was significantly lower than the international average score (M = 474, SE = 0.6). The South African scores displayed the widest range when compared against any other country.

In most countries there were equitable participation rates, with participation of girls and boys varying from 48 to 52 per cent. The international science average score for girls (M = 471, SE = 0.7) and for boys (M = 477, SE = 0.7) is worth commenting on, as this difference of 6 (SE = 0.6) is statistically significant, with boys outperforming girls. For South Africa, the girls average scale score was 242 (SE = 7.2) and the boys average scale score was 244 (SE =7.7). The difference is not statistically significant. In 11 countries the average science scores for girls and boys did not show a gender difference; in seven (7) countries the girls score was significantly higher than that of the boys; and in 28 countries the boys score was significantly higher than for the girls.

South Africa has 13 per cent of the population achieve a score higher than the LIB (that is, a score higher than 400). This means that 87 per cent of the learners scored lower than 400 scale points. This again illustrates the vast variation in South African performance – a few learners performing very well and the majority performing poorly. South Africa and Ghana had the highest number of learners scoring below the LIB.

National analysis: TIMSS 2003 mathematics

Chapter 3 of this report provided information on international mathematics achievement and on South Africa's performance in relation to the other participating countries. The value of TIMSS could be enhanced with further analysis aimed at providing information to policymakers and practitioners within South Africa, that is, by offering a national analysis. For the national analysis we used the TIMSS international dataset and added the following variables: name of province where the school is located and the ex-racial department of the school.[1] In the national analysis, disaggregated scores were calculated, scores linked to available contextual information, and there was an analysis of change of performance over time (TIMSS 1999 and 2003). The following elements comprised the national analysis undertaken:

- National mathematics participation and performance in TIMSS 1999 and 2003;
- Performance by province;
- Performance by ex-racial department of schools;
- Performance by gender;
- Performance by language of the test; and
- Performance by content area, cognitive domain and question type.

National mathematics participation and performance in TIMSS 1999 and 2003

The average age of South African learners in TIMSS 2003 (administered in November 2002) was 15.1 years. This is 0.4 years lower than the average age of 15.5 years of the TIMSS 1999 sample (administered in 1998). This drop in the average age, from 1998 to 2002, implies that there is either less repetition in the system or fewer learners leave the system and then re-enter. This would suggest that participation patterns in the system are improving.

The TIMSS 2003 national average mathematics scale score was 264 (SE = 5.5). The score in TIMSS 1999 was 275 (SE = 6.8). The 11 point decrease in the average mathematics scale score is not significant (see Chapter 3 for details).

The scores of learners were categorised at the different performance benchmarks. In TIMSS 1999, 13 per cent of the learners scored more than 400 points in the mathematics test, and this decreased to 10 per cent in TIMSS 2003. The low number of learners scoring higher than 400 points in both studies is cause for concern. Without achieving high scores at Grade 8 level, it is unlikely that learners would go on to attain high scores at Grade 12, so restricting their opportunity to pursue tertiary-level studies in science and/or engineering. The second concern is that the percentage of learners who scored higher than 400 has decreased from 13 per cent in TIMSS 1999 to 10 per cent in TIMSS 2003.

Performance by province

In South Africa, the national Department of Education is responsible for developing educational policies. The provincial departments of education are responsible for

1 The ex-racial department of school refers to the categorisation of schools during the apartheid era.

ensuring the implementation of these policies and supporting the delivery of a quality education. Each of the provinces has a different resource base and distinct advantages and disadvantages. It is important to compute the achievement scores for each of the provinces so that provincial policy-makers remain informed about the state of education in their area, and can then introduce strategies designed to improve matters. Appendix 2 provides a description of schools in the TIMSS 2003 sample, by province and by ex-racial department of the school.

Provincial scores

In South Africa, we oversampled the number of schools for the TIMSS national sample, so that there would be a sufficient number of cases to ensure the calculation of provincial scores. Table 5.1 indicates the average provincial mathematics scale score in TIMSS 2003.

Table 5.1: Average mathematics scale score by province

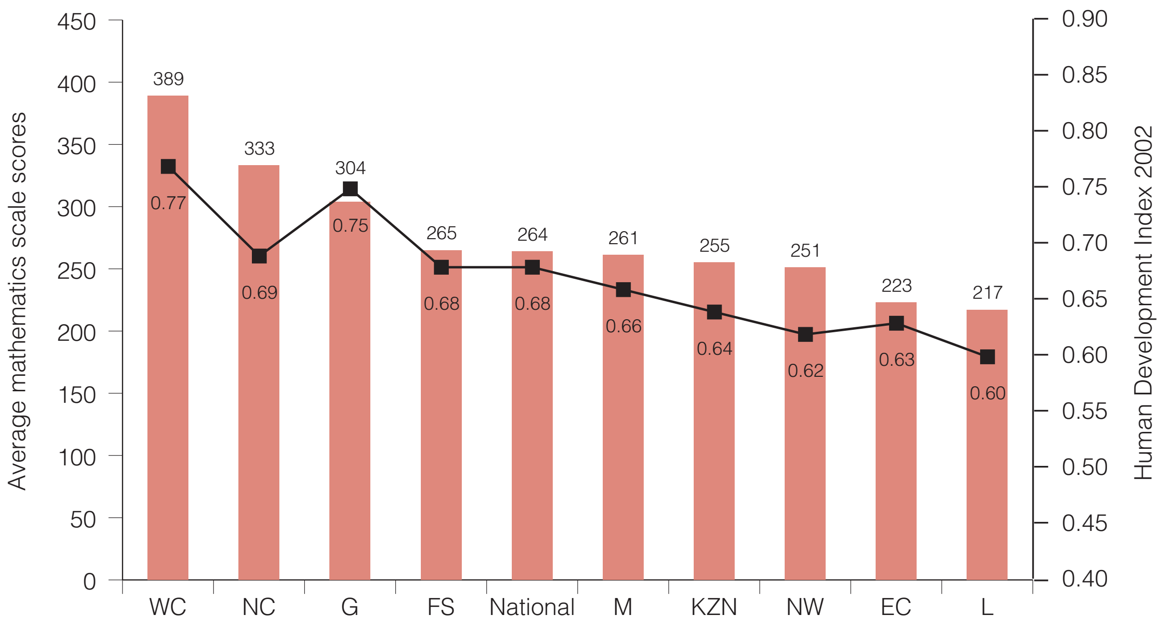
Province	Average mathematics scale score (SE)	Score range
Western Cape (n = 813)	389 (25.3)	96–677
Northern Cape (870)	333 (13.5)	70–673
Gauteng (774)	304 (19.1)	64–579
Free State (867)	265 (8.6)	45–630
National average (8 952)	264 (5.5)	5–690
Mpumalanga (962)	261 (22.4)	24–650
KwaZulu-Natal (1 632)	255 (13.7)	5–690
North West Province (946)	251 (17.2)	17–572
Eastern Cape (943)	223 (8.3)	5–570
Limpopo (1145)	217 (5.6)	5–455

The top three performing provinces were Western Cape, Northern Cape and Gauteng and the three lowest performing provinces were North West, Eastern Cape and Limpopo. The average provincial score ranges from 389 for the top performing province, Western Cape, to 217 for the lowest performing province, Limpopo – a difference of 172 score points. Three provinces – Western Cape, Northern Cape and Gauteng – scored significantly higher than the national average, and four provinces – KwaZulu-Natal, North West, Eastern Cape and Limpopo – scored significantly lower than the national average. Free State and Mpumalanga scored the same as the national average.

Provincial scores and the Human Development Index

The socio-economic conditions, and thus the conditions for teaching and learning, are different in each of the provinces. The HDI of each province (calculated by GDP per capita, literacy rate – measured by the adult literacy rate and combined primary, secondary and tertiary gross enrolment rates – and life expectancy at birth) provided an indication of socio-economic conditions. Figure 5.1 illuminates the provincial mathematics scale score and the provincial HDI.

Figure 5.1: Provincial mathematics scale scores and HDI, by province



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

There seems to be a correlation between the provincial HDI and the provincial achievement scores. Provinces with a higher HDI attained a higher achievement score than provinces with a lower HDI. Gauteng is an exception, and this may be due to the economic inequalities and variances existing across its population.

Comparison of TIMSS 1999 and TIMSS 2003 provincial scores

TIMSS is a trend study and it is useful to compare the provincial average scores over the two periods – 1999 and 2003 (see Table 5.2). Average provincial scores and the rank order of provinces changed. There was an increase in the scores of three provinces, while the others experienced a decrease. The provincial change in scores from TIMSS 1999 to TIMSS 2003 is not statistically significant.

Table 5.2: Provinces where scores increased or decreased between TIMSS 1999 and TIMSS 2003

Provinces where average scores increased	Provinces where average scores decreased
Western Cape (by 11 points)	KwaZulu-Natal (by 37 points)
Northern Cape (by 13)	Eastern Cape (by 26)
Mpumalanga (by 8)	Gauteng (by 14)
	Free State (by 11)
	North West (by 8)
	Limpopo (by 3)

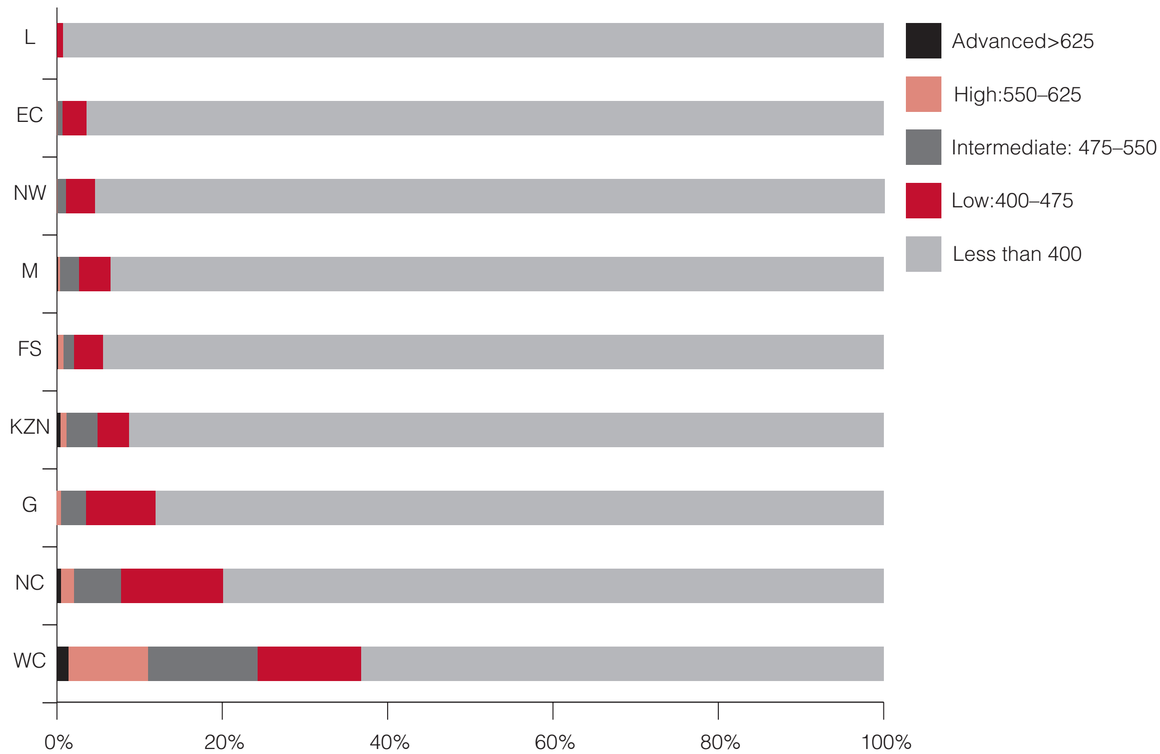
There has been a change in the rank order of some of the provinces from TIMSS 1999 to TIMSS 2003. Two provinces improved their rank order: Free State from 5 to 4 and

Mpumalanga from 7 to 5. Two provinces dropped in rank order: KwaZulu-Natal from 4 to 6 and North West from 6 to 7.

Performance of provinces at the different benchmarks

South Africa had 10 per cent of learners who achieved a score higher than 400 (that is, above the Low Performance Benchmark). Disaggregating the scores by provinces provided the following profile of performance (Figure 5.2). As expected, Western Cape had the highest number of learners achieving scores greater than 400, with just over one-third of learners achieving this. Western Cape is followed by Northern Cape and Gauteng. In Limpopo, none of the learners achieved scores higher than 475.

Figure 5.2: Provincial profile of mathematics performance at different benchmarks



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

Performance by ex-racial department of schools

Under apartheid, education was administered separately and unequally to the different racial groups. African schools were the most disadvantaged and white schools the most advantaged. It is important to include an analysis of learners' performance in schools categorised by ex-racial departments of education, as this indicates the performance of schools operating under different conditions, such as infrastructure, management and governance, educational culture, resource base, socio-economic status of learners, and so on. African schools are located in areas where mostly Africans live and these areas are characterised by high levels of poverty and unemployment. Ex-HoA schools, previously for white learners, exist in the better socio-economic conditions associated with a predominately white demographic.

Scores by ex-racial departments of schools

The disaggregated scores of learners in schools categorised by ex-racial departments in TIMSS 2003 are provided in Figure 5.3. There were large differences in the average scores of learners attending different school types. Learners who were in ex-HoA schools had an average score that was close to the international average. The average mathematics scale score (and SE) for schools of the ex-racial departments were as follows:

- ex-Department of Education and Training (DET) schools 227 (2.9);
- ex-House of Representatives (HoR) schools 314 (8.6);
- ex-House of Delegates (HoD) schools 366 (24.9); and
- ex-House of Assembly (HoA) schools 468 (20.3).[2]

Presently, the racial profile of learners in the ex-HoR, ex-HoD and ex-HoA schools indicates that there is racial integration, and that in ex-DET schools the learner population is essentially African.

Figure 5.3: Average mathematics scale scores of learners from the different school types

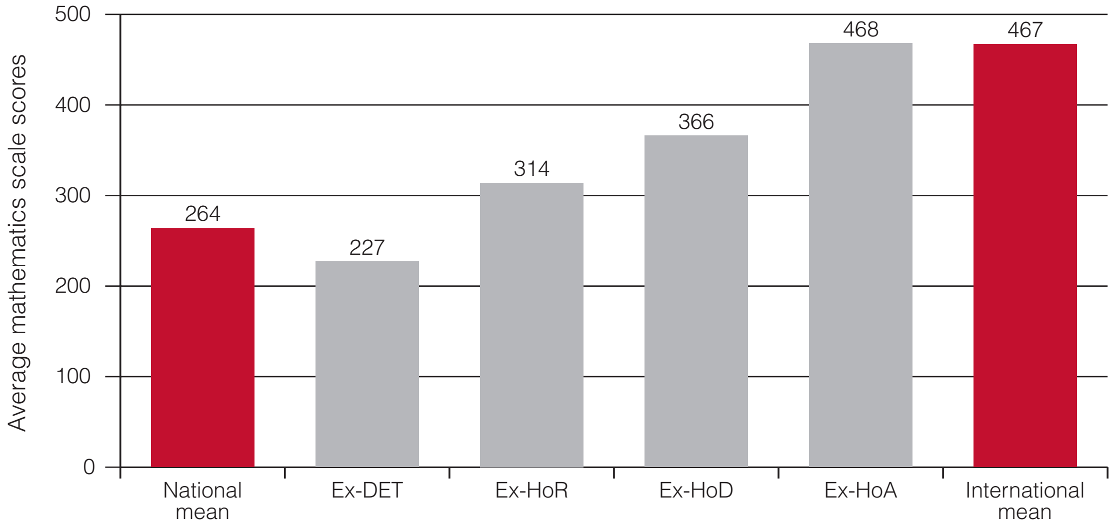
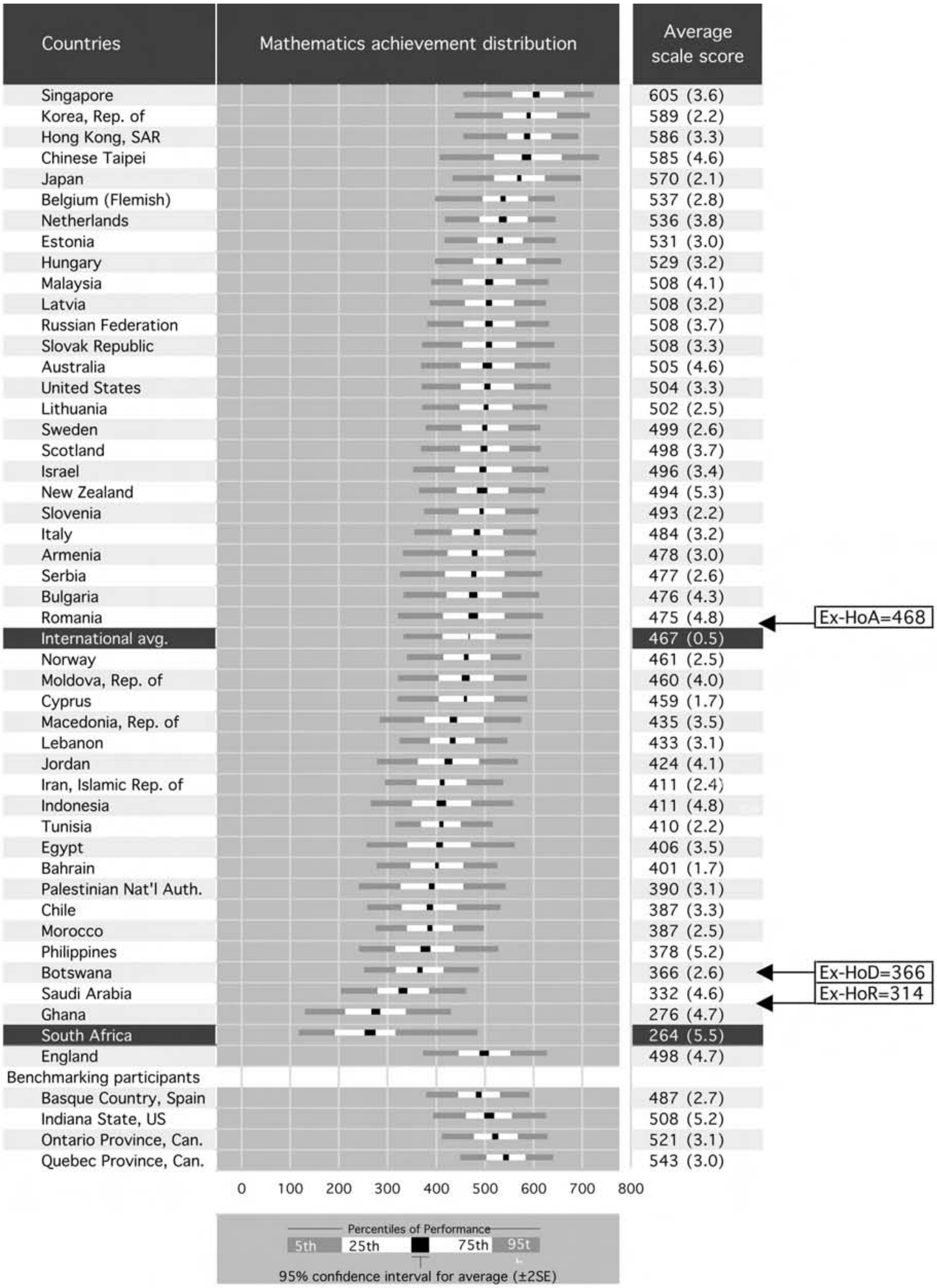


Figure 5.4 provides an indication of how the different school types would have fared in the international comparison.

2 There were 8 952 cases. Of these, 6 697 learners were in ex-DET schools (for African learners); 1 211 learners were in ex-HoR schools (previously for coloured learners); 303 learners were in ex-HoD schools (previously for Indian learners), and 741 learners were in ex-HoA schools (previously for white learners). Although the numbers for ex-HoD and ex-HoA schools are low, the scores can be considered as indicative of performance in these schools.

Figure 5.4: Distribution of mathematics achievement



Comparison of scores of schools from ex-racial departments for TIMSS 1999 and 2003

TIMSS 1999 data was collected in 1998 and TIMSS 2003 data was collected in 2002. The racial profile of learners in the different school types changed from TIMSS 1999 to TIMSS 2003. The profile of racial integration is provided in Table 9.2 in Chapter 9. Table 5.3 provides information of how the performance of learners in schools, categorised by ex–racial department, changed between TIMSS 1999 and TIMSS 2003.

Table 5.3: Change in mathematics performance, from TIMSS 1999 to TIMSS 2003, by ex-racial department

School type	1999 average scale score (SE)	2003 average scale score (SE)	1999–2003 difference
Ex-DET	238 (4.9) (n = 6 166)	227 (2.9) (n = 6 697)	-11*
Ex-HoR	348 (16.1) (n = 1 059)	314 (8.6) (n = 1 211)	-34
Ex-HoD	406 (14.3) (n = 212)	366 (24.9) (n = 303)	-40
Ex-HoA	442 (18.0) (n = 709)	468 (20.3) (n = 741)	25
National average	275 (6.8)	264 (5.5)	-11

** Difference is statistically significant.*

There was a decrease in the average mathematics score in the ex-DET, ex-HoR and ex-HoD schools in the period 1999 to 2003. The decrease in ex-DET schools is significant at the 95 per cent confidence level and in ex-HoR schools it is 'not quite' significant. There was an increase in average mathematics scores, of 25 points, in ex-HoA schools, but this is not statistically significant.

Since 1998 (with the introduction of C2005) there have been many professional development courses and programmes for teachers. In addition, numerous interventions by government, private sector, business and non-governmental organisations have been made in schools, especially the African schools, with the objective of improving the state of mathematics and science education. However, it seems that despite these programmes there has been a decrease in mathematics performance in many schools.

Performance by gender

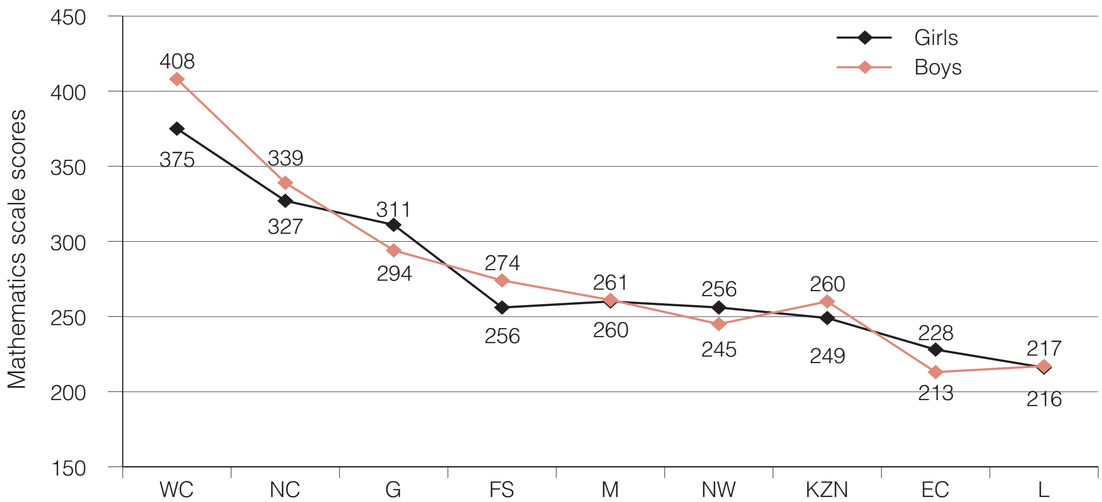
National scores

In the national sample, there was an almost equal participation by girls and boys. Nationally, the performance between girls and boys is similar, with the girls scoring 262 (SE = 6.2) and the boys scoring 264 (SE = 6.4) in TIMSS 2003. There has, however, been a change in the scores of the girls and boys since TIMSS 1999, when the girls score was 268 (SE = 7.5) and the boys score was 283 (SE = 7.3). In neither year has the difference in score between girls and boys been statistically significant. The scores of the girls decreased by 6 points from TIMSS 1999 to TIMSS 2003 and the scores of the boys decreased by 19 points over the same time period. These across-year differences are not statistically significant.

Provincial performance by gender

Figure 5.5 provides a picture of provincial mathematics achievement scores for girls and boys.

Figure 5.5: Mathematics performance of girls and boys by province



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

The scores of boys (in order of magnitude) were higher than the girls in Western Cape (by 33), Free State (18), Northern Cape (12), KwaZulu-Natal (11), Mpumalanga (1) and Limpopo (1). The scores of girls were higher in Gauteng (by 17), Eastern Cape (15) and North West (11). As in the national sample, the difference in the scores between boys and girls in the provinces is not statistically significant.

Performance at different benchmarks, by gender

There was a similar number of girls and boys, at 10.2 and 10.8 per cent respectively, who achieved scores higher than 400 (the LIB). In both cases, the number of learners is low. An improvement on this situation presents a strong challenge to the education system.

Gender scores by ex-DoE

The national and provincial scores indicated that there was no statistically significant gender difference in the mathematics scores of girls and boys. It is important to investigate gender differences in performance for learners in different socio-economic conditions. Using the ex-racial departments of schools as a proxy for social class, the average mathematics scores for the different groups was calculated. Table 5.4 shows the performance of girls and boys, in TIMSS 2003 and TIMSS 1999, by school type.

Table 5.4: Mathematics performance in schools categorised by ex-racial department, for TIMSS 1999 and TIMSS 2003, by gender

		TIMSS 1999			TIMSS 2003		
Ex-dept	Gender	No.	Score (SE)	Difference: boy–girl	No.	Score (SE)	Difference: boy–girl
Ex-DET	Girl	3 260	231 (4.8)	16*	3 401	228 (3.2)	-2
	Boy	2 906	247 (5.7)		3 267	226 (3.4)	
Ex-HoA	Girl	365	431 (20.8)	24	350	464 (19.0)	8
	Boy	344	455 (16.2)		390	472 (24.3)	
Ex-HoR	Girl	551	349 (19.0)	-2	601	309 (8.3)	10
	Boy	508	347 (14.9)		528	319 (11.2)	
Ex-HoD	Girl	114	409 (15.2)	-8	126	355 (24.8)	18
	Boy	98	401 (15.8)		177	373 (27.5)	
Total	Girl	4 290	267 (7.5)	16	4 478	262 (6.2)	2
	Boy	3 856	283 (7.4)		4 362	264 (6.4)	

** Difference is statistically significant at the 95% confidence level.*

In TIMSS 2003, for ex-DET schools, the scores of girls were higher than those of the boys. The average score of schools of the other ex-departments indicated that the boys achieved higher scores than the girls. In none of the categories was the difference statistically significant. In TIMSS 1999, the score of the girls in ex-DET schools was lower than those of the boys and this difference was statistically significant. In the other school types, there was no statistically significant difference in the scores of girls and boys. The TIMSS 1999 scores suggested that in poorer socio-economic conditions girls experienced the greater disadvantage in mathematics performance. The TIMSS scores over the two periods (1999 and 2003) indicated that the gender difference in mathematics performance had decreased in ex-DET schools. While it is a positive feature that the gender gap in performance is decreasing, the overall performance of both groups is still low, and of concern.

Performance by language of the test

Schools were asked to indicate their language of teaching and learning. Although South Africa has 11 official languages, schools indicated two languages of instruction: English or Afrikaans. Learners were then given the TIMSS instruments in either English or Afrikaans. Appendix 3 provides an analysis of schools who took the TIMSS test in Afrikaans, by province and ex-racial department of the school. The average scale score of the learners for these two groups, according to the language of the instrument, is shown in Table 5.5.

Table 5.5: Average mathematics score by language of instruction

Language of instruction	Mathematics scale score (SE)
English (n = 7 912)	253 (5.7)
Afrikaans (n = 1 040)	370 (23.5)

There were 1 040 learners who answered in Afrikaans. These learners came from different provinces and schools categorised by ex-department. Many of the learners taking the test in Afrikaans attended either ex-HoR or ex-HoA schools, and these schools are mostly in the Northern or Western Cape. These learners would have taken the test in their home language and the average score of 370 would place this learner group just above the score for Botswana on the international table. For the learners who took the test in English, most would be attending ex-DET schools and English would not be their first language. While the language of the test and the learners' proficiency in that language contributed to the achievement scores attained, it is difficult to determine the extent of this contribution as there are other inequalities among the different school types and these also influence performance.

Performance by content area, cognitive domain and question type

Analysis of the percentage of learners who correctly answered each item provides a useful picture of what South African learners know, and can do, in mathematics. The following analyses – by content area, cognitive domain and question type – provide a profile of how learners answered each item.

Performance by content domain

The TIMSS 2003 mathematics tests were designed to enable reporting on five content areas, in accordance with the TIMSS mathematics framework. The five content areas (and % of items in the test) were:

- *Number (30%)*. This domain included understanding of counting and numbers, ways of representing numbers, relationships amongst numbers, and number systems.
- *Algebra (25%)*. This domain included patterns and relationships among quantities, using algebraic symbols to represent mathematical situations, and developing fluency in producing equivalent expressions and solving linear equations.
- *Measurement (15%)*. This domain focused on understanding and demonstrating familiarity with the units and processes used in measuring various attributes.
- *Geometry (15%)*. This domain focused on analysing the properties and characteristics of geometric figures, including lines, angles and two- and three-dimensional shapes, and providing explanations based on geometric relationships.
- *Data (15%)*. This domain focused on understanding how to collect data, and organising and displaying data in graphs and charts.

The content area scores were scaled to compare the relative performances. South Africa's performance in each of these areas is indicated in Table 5.6.

Table 5.6: Relative mathematics scale scores (and SE) in the content domains

Number	Algebra	Measurement	Geometry	Data
274 (5.4)	275 (5.1)	298 (4.7)	247 (5.4)	296 (5.3)

South African learners performed relatively well in the domains of measurement and data, and scored lowest in the domain of geometry.

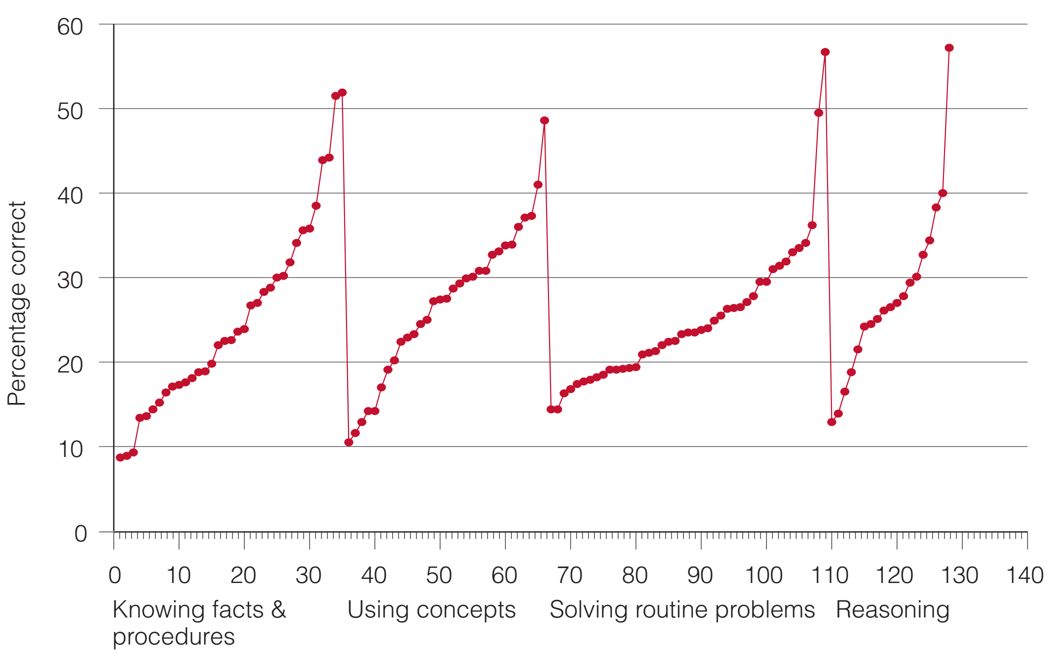
Performance by cognitive domain

The TIMSS 2003 mathematics items were categorised into one of four cognitive domains. The cognitive domains define the behaviours expected of learners as they engage with the mathematics content. The four cognitive domains (and % of items in the test) were:

- *Knowing facts and procedures (15%)*. Performing mathematics depends on mathematical knowledge. Facts encompass the knowledge providing the basic language of mathematics, and procedures provide the link to solving routine problems through applying this knowledge.
- *Using concepts (20%)*. Knowledge of concepts enables learners to make connections between elements of knowledge that would otherwise be retained as isolated facts.
- *Solving routine problems (40%)*. Problem solving is of crucial importance, and often the means of teaching mathematics. In items categorised in this domain, the problem settings are more routine than those aligned with the reasoning domain.
- *Reasoning (25%)*. Reasoning mathematically indicates the capacity for logical, systematic thinking, and includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems.

Figure 5.6 provides a profile of how South African learners answered each multi-choice question (MCQ) item, categorised according to the four cognitive domains.

Figure 5.6: Percentage of learners who correctly answered items in each cognitive domain



Although there is a hierarchical nature to the cognitive domains, with the *knowing facts and procedures* domain considered to be at a lower cognitive level than the *reasoning* domain, the performance in each of the domains is similar, that is, there is a similar distribution of correct answers across the domains. In each of the cognitive domains, on most items less than 30 per cent of the learners scored correctly. One would have expected a higher percentage of correct answers on items in the *knowing facts and procedures* and *using concepts* categories. Therefore, performance in the *reasoning* domain is, relatively speaking, good.

Performance by question type

Learners' knowledge and understanding of mathematics was assessed by MCQs and constructed-response questions. There were 128 MCQ items and 66 constructed-response items. The percentage of correct answers for the MCQ items ranged from 8.7 to 57.0 per cent. In the constructed-response questions, learners performed very poorly, with most of the items being answered correctly by less than 10 per cent of the learners. Figure 5.7 illustrates the percentage of learners correctly answering the MCQ items in the five content areas.

Figure 5.7: Percentage of learners who answered the MCQ items correctly

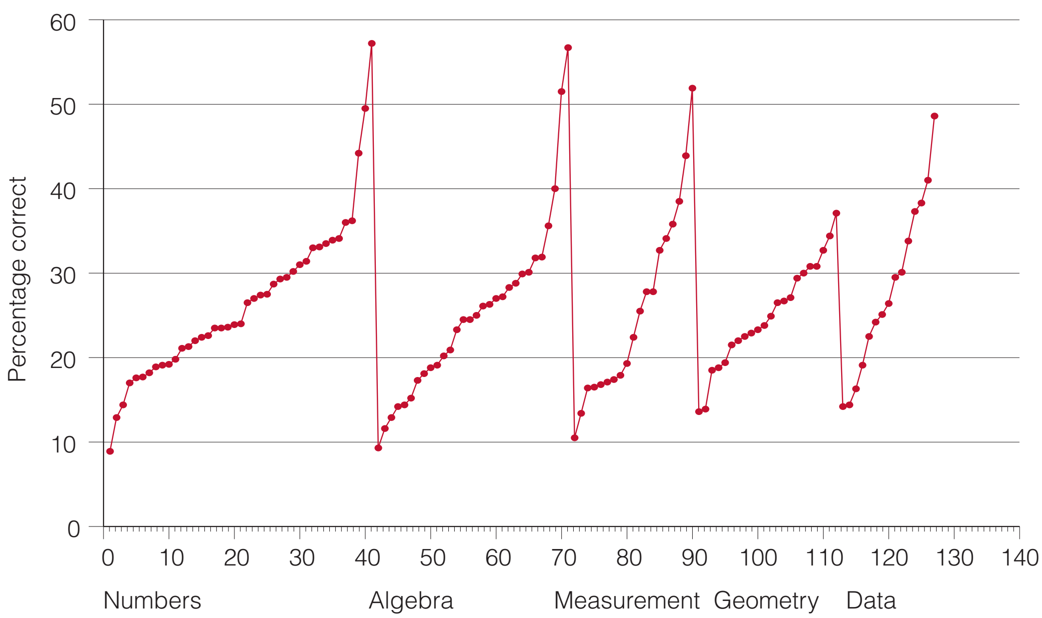


Figure 5.7 shows that for most items less than 30 per cent of learners answered correctly. On only five MCQ items did more than half the learners respond correctly. The profile of learners' response rates for the content domains – number, algebra, measurement and data – is similar. In the area of geometry, however, there were fewer learners who answered correctly.

Summary

From TIMSS 1999, there was a drop in the average age of learners who participated in TIMSS 2003. This implies that there is either less repetition, or fewer learners leave the system and then re-enter – suggesting that participation patterns are improving.

There is a difference in the performance of the country's provinces. The top three performing provinces were Western Cape, Northern Cape and Gauteng, and the three poorest performing provinces were North West, Eastern Cape and Limpopo. With the exception of Gauteng, there was an observable correlation between the provincial mathematics scale scores and the HDI rating.

Learners attending different school types achieved different average scores. Learners who attended ex-HoA schools achieved a score close to the international average. The average mathematics scale score (and SE) for schools of the ex-racial departments were: ex-DET schools, 227 (2.9); ex-HoR schools, 314 (8.6); ex-HoD schools, 366 (24.9); and ex-HoA schools, 468 (20.3).

There was a decrease in the average score in the ex-DET, ex-HoR and ex-HoD schools in the period 1999 to 2003. The decrease is significant in the ex-DET schools. There was an increase of 25 points in average mathematics scores in ex-HoA schools over the period 1999 to 2003.

Nationally, the performance between girls and boys was similar, with the girls scoring 262 (6.2) and the boys scoring 264 (6.4). Provincially, there was also no gender difference in mathematics performance.

Learners who answered the questions in English and Afrikaans achieved different average scores. Many learners who answered in English were not answering in their home language, and this may explain the lower score attained – 253, compared to 370 for learners answering in Afrikaans.

Learners performed relatively well in the content domains of measurement and data. The performance level was lowest in the geometry domain.

National analysis: TIMSS 2003 science

Chapter 4 provided information on international science achievement and on South Africa's performance in relation to the other participating countries. The value of TIMSS could be enhanced with further analysis aimed at providing information to policymakers and practitioners within South Africa, that is, by offering a national analysis. For the national analysis we used the TIMSS international dataset and added the following variables: name of province where the school is located and the ex-racial department of the school.[1] In the national analysis, disaggregated scores were calculated, scores linked to available contextual information, and there was an analysis of change of performance over time (TIMSS 1999 and 2003). The following elements comprised the national analysis undertaken:

- National science participation and performance in TIMSS 1999 and 2003;
- Performance by province;
- Performance by ex-racial department of schools;
- Performance by gender;
- Performance by language of the test; and
- Performance by content area, cognitive domain and question type.

National science participation and performance in TIMSS 1999 and TIMSS 2003

The average age of South African learners in TIMSS 2003 (administered in November 2002) was 15.1 years. This is 0.4 years lower than the average age of 15.5 years of the TIMSS 1999 sample (administered in 1998). This drop in the average age, from 1998 to 2002, implies that there is either less repetition in the system or fewer learners leave the system and then re-enter. This would suggest that participation patterns in the system are improving.

The TIMSS 2003 national average science scale score was 244 (SE 6.7). The score in TIMSS 1999 was 243 (SE 8.8). The one point increase in the average science scale scores is not significant (see Chapter 4 of this report for details).

The scores of learners were categorised at the different performance benchmarks. In TIMSS 1999, 13.9 per cent of the learners scored more than 400 points in the science test, and this decreased to 12.4 per cent in TIMSS 2003. The low number of learners scoring higher than 400 points in both studies is cause for concern. Without achieving high scores at Grade 8 level, it is unlikely that learners would go on to attain high scores at Grade 12, so restricting their opportunity to pursue tertiary level studies in science and/or engineering. The second concern is that the percentage of learners who scored higher than 400 has decreased from 13.9 per cent in TIMSS 1999 to 12.4 per cent in TIMSS 2003.

Performance by province

In South Africa, the national Department of Education is responsible for developing educational policies. The provincial departments of education are responsible for ensuring the implementation of these policies and supporting the delivery of a quality

1 The ex-racial department of school refers to the categorisation of schools during the apartheid era.

education. Each of the provinces has a different resource base and distinct advantages and disadvantages. It is important to compute the achievement scores for each of the provinces so that provincial policy-makers remain informed about the state of education in their area, and can then introduce strategies designed to improve matters. Appendix 2 provides a description of schools in the TIMSS 2003 sample, by province and by ex-racial department of the school.

Provincial scores

In South Africa, we oversampled the number of schools for the TIMSS national sample, so that there would be a sufficient number of cases to ensure the calculation of provincial scores. Table 6.1 indicates the average provincial science scale score in TIMSS 2003.

Table 6.1: Average science scale scores by province

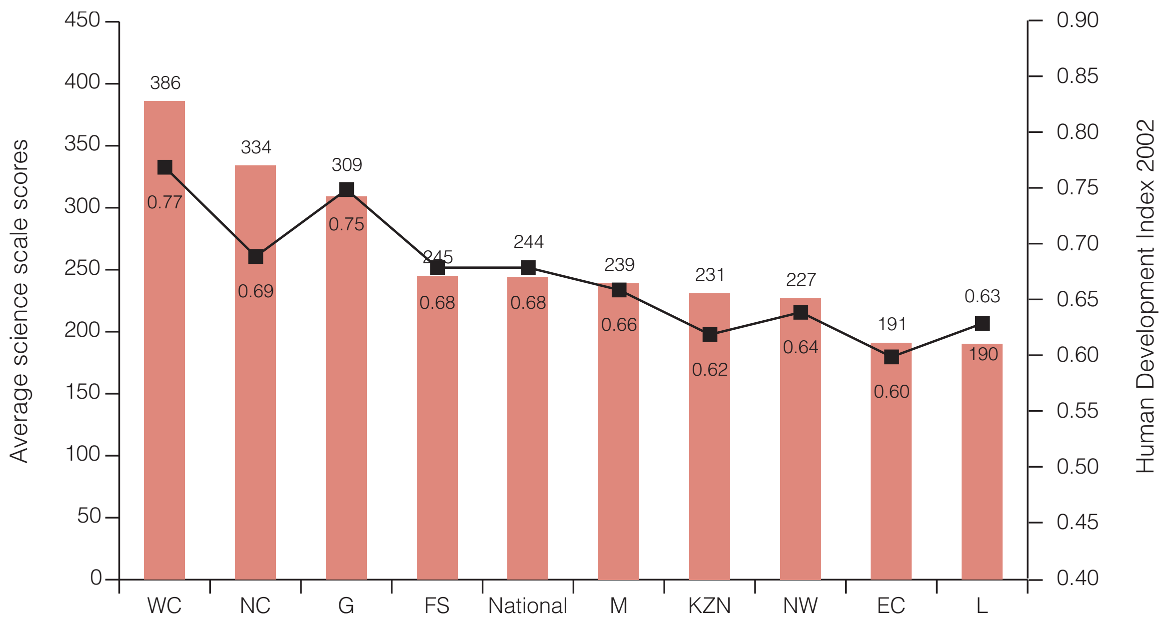
Province	Average science scale score (SE)	Score range
Western Cape (n = 813)	386 (28.1)	5–707
Northern Cape (n = 870)	334 (13.9)	5–687
Gauteng (n = 774)	309 (22.9)	11–666
Free State (n = 867)	245 (9.3)	5–622
National average (n = 8 952)	244 (6.7)	5–707
Mpumalanga (n = 962)	239 (28.5)	5–621
North West Province (n = 946)	231 (21.5)	5–571
KwaZulu Natal (n = 1 632)	227 (16.5)	5–684
Limpopo (n = 1 145)	191 (6.6)	5–506
Eastern Cape (n = 943)	190 (10.0)	5–527

The top three performing provinces were Western Cape, Northern Cape and Gauteng and the three lowest performing provinces were KwaZulu-Natal, Limpopo and Eastern Cape. The average provincial score ranges from 386 for the top performing province, Western Cape, to 190 for the lowest performing province, Limpopo. This means that the top performing province had double the score of the lowest performing province. Three provinces – Western Cape, Northern Cape and Gauteng – scored significantly higher than the national average, and three provinces – KwaZulu-Natal, Limpopo and Eastern Cape – scored significantly lower than the national average.

Provincial scores and the HDI

The socio-economic conditions, and thus the conditions for teaching and learning, are different in each of the provinces. The HDI of each province (calculated by GDP per capita, literacy rate – measured by the adult literacy rate and combined primary, secondary and tertiary gross enrolment rates – and life expectancy at birth) provided an indication of socio-economic conditions. Figure 6.1 illuminates the provincial mathematics scale score and the provincial HDI.

Figure 6.1: Provincial science scale scores and HDI, by province



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

There seems to be a correlation between the provincial HDI and the provincial achievement score. Provinces with a higher HDI attained a higher achievement score than provinces with a lower HDI. Gauteng is an exception, and this may due to the economic inequalities and variances existing across its population.

Comparison of TIMSS 1999 and TIMSS 2003 provincial scores

TIMSS is a trend study and it is useful to compare the provincial average scores over the two periods – 1999 and 2003 (see Table 6.2). Average provincial scores and the rank order of provinces changed. There was an increase in the scores of three provinces, while the others experienced a decrease. The increase in scores for Northern Cape and Limpopo was statistically significant. In all other cases the scores changes were not statistically significant.

Table 6.2: Provinces where scores increased or decreased between TIMSS 1999 and TIMSS 2003

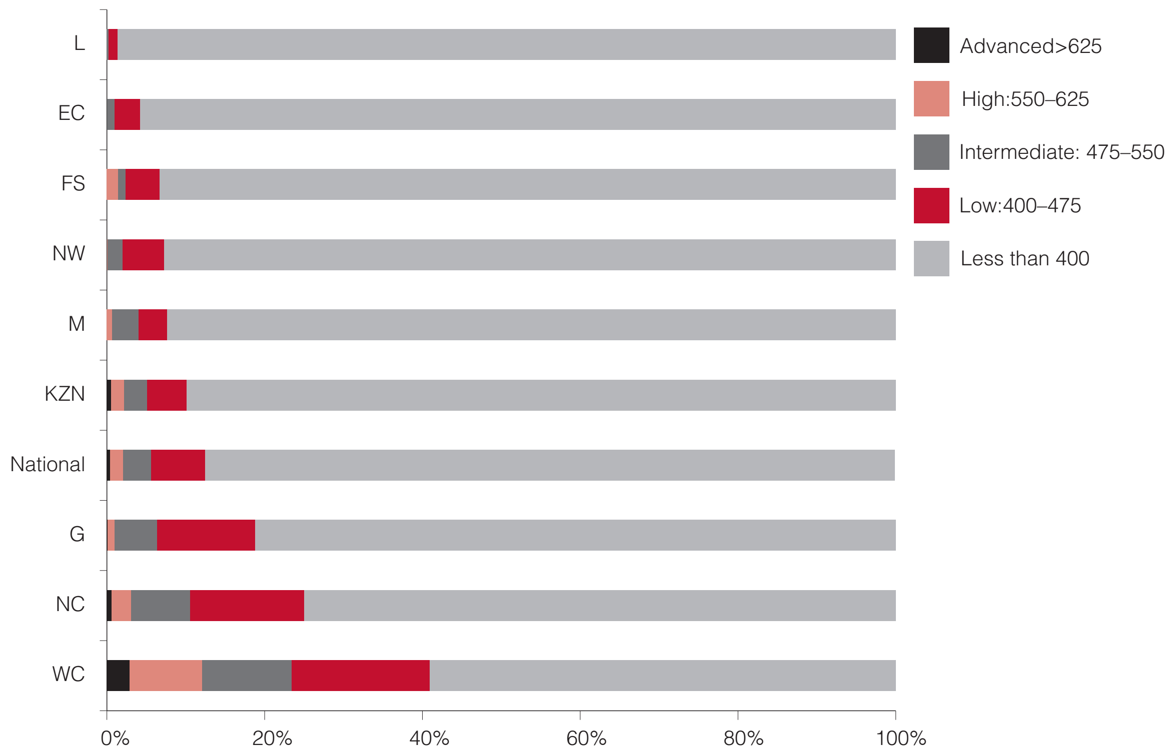
Provinces where average scores increased	Provinces where average scores decreased
Northern Cape (by 51 points)	KwaZulu-Natal (by 31 points)
Limpopo (by 22)	Eastern Cape (by 16)
Mpumalanga (by 7)	Free State (by 10)
	Western Cape (by 7)
	North West (by 4)
	Gauteng (by 3)

There has been a change in the rank order of some of the provinces from TIMSS 1999 to TIMSS 2003. Three provinces improved their rank order: Northern Cape from 3 to 2, Free State from 5 to 4 and Mpumalanga from 7 to 5. Two provinces dropped in rank order: Gauteng from 2 to 3 and KwaZulu-Natal from 4 to 7.

Performance of provinces at the different benchmarks

South Africa had 12.4 per cent of learners who achieved a score higher than 400 (that is, above the Low Performance Benchmark). Disaggregating the scores by provinces provided the following profile of performance (Figure 6.2). As expected, Western Cape had the highest number of learners achieving scores greater than 400, followed by Northern Cape and Gauteng. In Limpopo, none of the learners achieved scores higher than 475.

Figure 6.2: Provincial profile of science performance at different benchmarks



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

Performance by ex-racial department of schools

Under apartheid, education was administered separately and unequally to the different racial groups. African schools were the most disadvantaged and white schools the most advantaged. It is important to include an analysis of learners' performance in schools categorised by ex-racial departments of education, as this indicates the performance of schools operating under different conditions, such as infrastructure, management and governance, educational culture, resource base, socio-economic status of learners, and so on. African schools are located in areas where mostly Africans live and these areas are characterised by high levels of poverty and unemployment. Ex-HoA schools, previously for white learners, exist in the better socio-economic conditions associated with a predominately white demographic.

Scores by ex-racial departments of schools

The disaggregated scores of learners in schools categorised by ex-racial departments in TIMSS 2003 are provided in Figure 6.3. There were significant differences in the average scores of learners attending different school types. Learners who were in ex-HoA schools had an average score that was just above the international average. The average science scale score (and SE) for schools of the ex-racial departments were as follows:

- ex-DET schools 199 (3.9);
- ex-HoR schools 311 (9.9);
- ex-HoD schools 371 (27.3); and
- ex-HoA schools 483 (17.3). [2]

Presently, the racial profile of learners in the ex-HoR, ex-HoD and ex-HoA schools indicates that there is racial integration, and that in ex-DET schools the learner population is essentially African.

Figure 6.3: Average science scale score of learners from the different school types

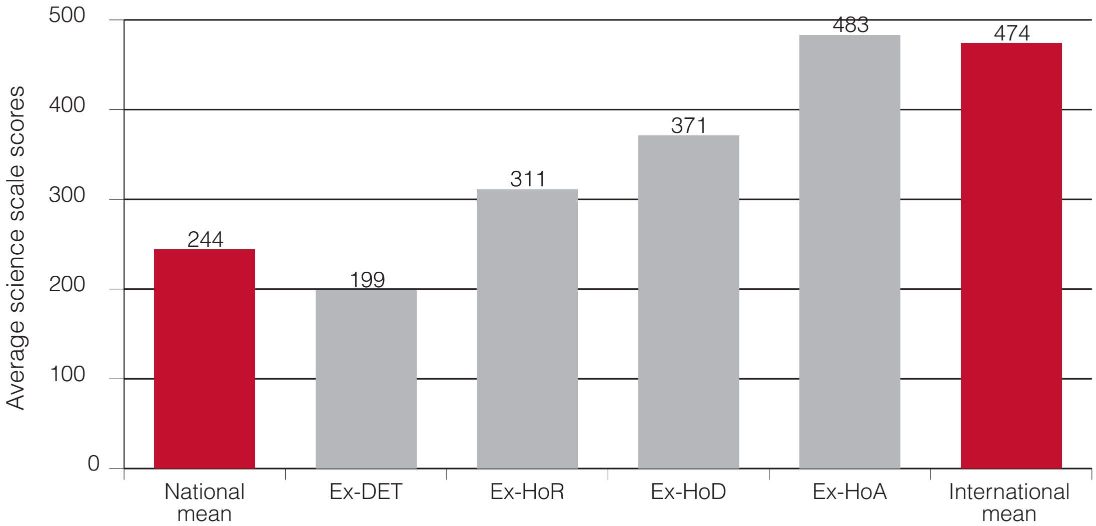
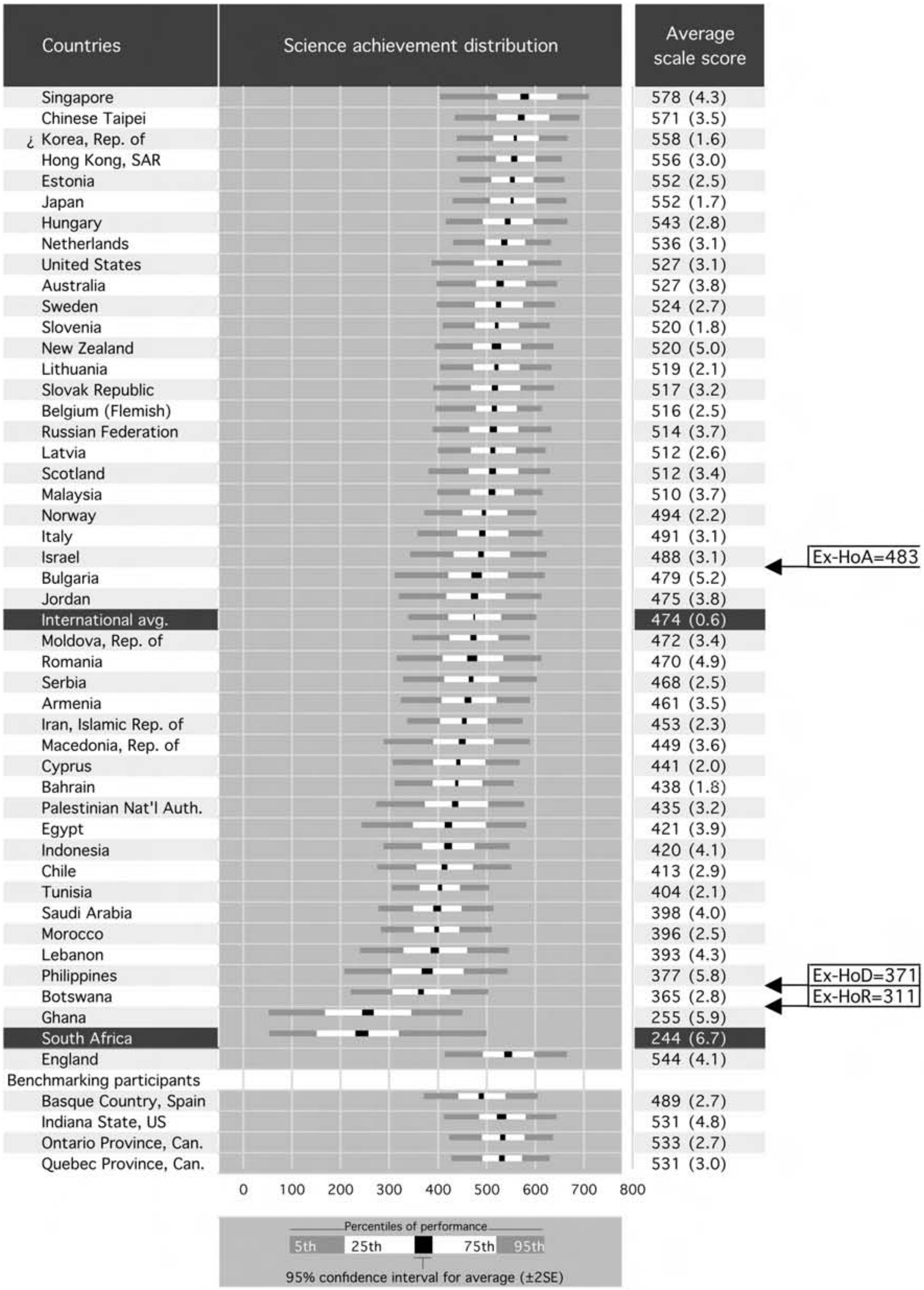


Figure 6.4 provides an indication of how the different school types would have fared in the international comparison.

2 There were 8 952 cases in total. Of these, 6 697 learners were in ex-DET schools (for African learners); 1 211 learners were in ex-HoR schools (previously for coloured learners); 303 learners were in ex-HoD schools (previously for Indian learners), and 741 learners were in ex-HoA schools (previously for white learners). Although the numbers for ex-HoD and ex-HoA schools are low, the scores can be considered as indicative of schools in these categories.

Figure 6.4: Distribution of science achievement



Comparison of scores of schools from ex-racial departments for TIMSS 1999 and 2003

TIMSS 1999 data was collected in 1998 and TIMSS 2003 data was collected in 2002. The racial profile of learners in the different school types changed from TIMSS 1999 to TIMSS 2003. The profile of racial integration is provided in Table 9.2 in Chapter 9. Table 6.3 provides information of how the performance of learners in schools, categorised by ex-racial department, changed between TIMSS 1999 and TIMSS 2003.

Table 6.3: Change in science performance from TIMSS 1999 to TIMSS 2003, by ex-racial department

	1999 average scale score (SE)	2003 average scale score (SE)	1999–2003 difference
Ex-DET schools	195 (3.8) (n = 6 166)	199 (3.9) (n = 6 697)	4
Ex-HoR schools	348 (17.1) (n = 1 059)	311 (9.9) (n = 1 211 059)	-37
Ex-HoD schools	420 (16.7) (n = 212)	371 (26.3) (n = 303)	-49
Ex-HoA schools	457 (25.1) (n = 709)	483 (17.3) n = 741	26
National average	243 (7.8)	244 (6.7)	1

There was a decrease in the average science score in the ex-HoR (with the difference being 'not quite' significant) and ex-HoD schools. There was an increase in average science scores in ex-DET schools (by 4 points) and in ex-HoA schools (by 26 points), but none of these changes are statistically significant.

Since 1998 (with the introduction of C2005) there have been many professional development courses and programmes for teachers. In addition, numerous interventions by government, private sector, business and non-governmental organisations have been made in schools, especially the African schools, with the objective of improving the state of mathematics and science education. The result of these interventions has been that some schools have shown an increase in performance, while others display decreased performance levels.

Performance by gender

National scores

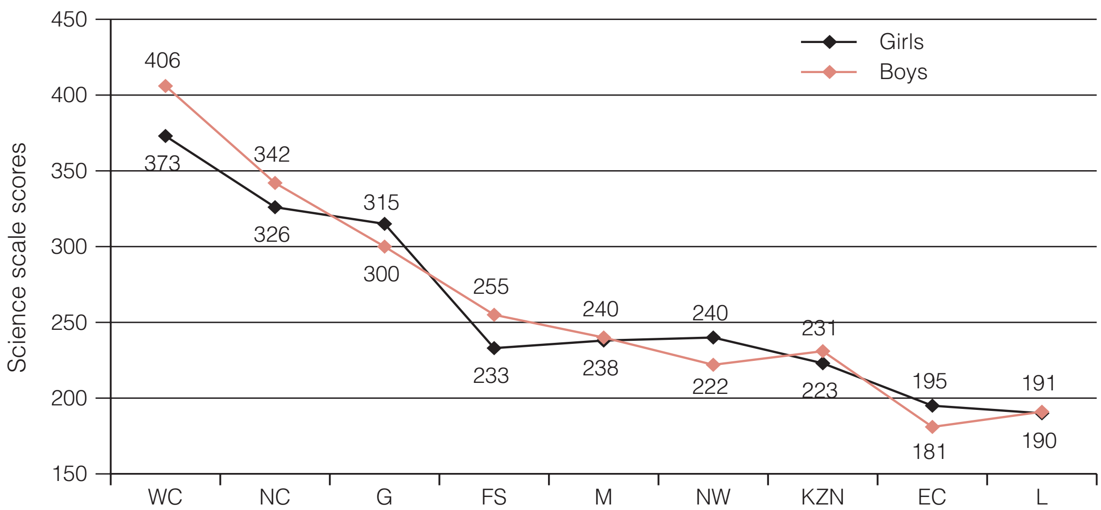
In the national sample, there was an almost equal participation by girls and boys. Nationally, the performance between girls and boys is similar, with the girls scoring 242 (SE = 7.2) and the boys scoring 244 (SE = 7.7) in TIMSS 2003. This two-point difference is not significant. There has, however, been a change in the scores of the girls and boys since TIMSS 1999, when the girls score was 234 (SE = 9.2) and the boys score was 233 (SE = 7.7). In neither year has the difference in score between girls and boys been statistically significant. The scores of the girls increased by 8 points from TIMSS

1999 to TIMSS 2003 and the scores of the boys decreased by 9 points over the same time period. These across-year differences are not statistically significant.

Provincial performance by gender

Figure 6.5 provides a picture of provincial science achievement scores for girls and boys, by province.

Figure 6.5: Science performance of girls and boys by province



Note: WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

The scores of boys (in order of magnitude) were higher than the girls in the Western Cape (by 33), Free State (22), Northern Cape (16), KwaZulu-Natal (8), Mpumalanga (2) and Limpopo (1). The scores of girls were higher in North West (18), Gauteng (15) and Eastern Cape (14). As in the national sample, the difference in the scores between boys and girls in the provinces is not statistically significant.

Performance at different benchmarks, by gender

There was a similar number of girls and boys, at 12 and 13 per cent respectively, who achieved scores higher than 400 (the LIB). In both cases, the number of learners is low. An improvement on this situation presents a strong challenge to the education system.

Gender scores by ex-DoE

The national and provincial scores indicated that there was no statistically significant gender difference in the science scores of girls and boys. It is important to investigate gender differences in performance for learners in different socio-economic conditions. Using the ex-racial departments of schools as a proxy for social class, the average science scores for the different groups was calculated. Table 6.4 indicates the performance of girls and boys, in TIMSS 2003 and TIMSS 1999, by school type.

Table 6.4: Science performance in schools categorised by ex-racial department, for TIMSS 1999 and TIMSS 2003, by gender

Ex-dept	Gender	TIMSS 1999			TIMSS 2003		
		No.	Score (SE)	Difference: boy–girl	No.	Score (SE)	Difference: boy-girl
Ex-DET	Girl	3 260	186 (4.4)	19*	3 401	200 (4.3)	-3
	Boy	2 906	205 (3.9)		3 267	197 (4.3)	
Ex-HoA	Girl	365	441 (31.2)	34	350	475 (15.7)	16
	Boy	344	475 (18.6)		390	491 (21.8)	
Ex-HoR	Girl	551	351 (23.1)	-6	601	307 (10.4)	7
	Boy	508	345 (13.9)		528	314 (13.5)	
Ex-HoD	Girl	114	424 (15.1)	-9	126	366 (26.7)	9
	Boy	98	415 (23.8)		177	375 (28.6)	
Total	Girl	4 290	234 (9.2)	19	4 362	242 (7.2)	2
	Boy	3 856	253 (7.7)		4 478	244 (7.7)	

** Difference is statistically significant at the 95% confidence level.*

In TIMSS 2003, for ex-DET schools, the scores of girls were higher than those of the boys. The average score of schools of the other ex-departments indicated that the boys achieved higher scores than the girls. In none of the categories was the difference statistically significant. In TIMSS 1999 the score of the girls in ex-DET schools was 19 points lower than those of boys and this difference was statistically significant. In ex-HoA schools girls scored 34 points fewer than the boys, but the difference was not statistically significant. The TIMSS scores indicate that the gender difference in science achievement scores, from TIMSS 1999 to TIMSS 2003, has decreased in ex-DET and ex-HoA schools.

Performance by language of the test

Schools were asked to indicate their language of teaching and learning. Although South Africa has 11 official languages, schools indicated two languages of instruction: English or Afrikaans. Learners were then given the TIMSS instruments in either English or Afrikaans. Appendix 3 of this report provides an analysis of schools who took the TIMSS test in Afrikaans, by province and ex-racial department of the school. The average scale score of the learners for these two groups, according to the language of the instrument, is shown in Table 6.5.

Table 6.5: Average science score by language of instruction

Language of instruction	Science scale score (SE)
English (n = 7 912)	231 (6.9)
Afrikaans (n = 1 040)	376 (26.4)

There were 1 040 learners who answered in Afrikaans. These learners came from different provinces and schools categorised by ex-department. Many of the learners taking the test in Afrikaans attended either ex-HoR or ex-HoA schools, and these schools are mostly in the Northern or Western Cape. These learners would have taken the test in their home language and the average score of 376 would place this learner group just above the score for Botswana on the international table. For the learners who took the test in English, most would be attending ex-DET schools and English would not be their first language. While the language of the test and the learners' proficiency in that language contributed to the achievement scores attained, it is difficult to determine the extent of this contribution as there are other inequalities among the different school types and these also influence performance.

Performance by content area, cognitive domain and question type

Analysis of the percentage of learners who correctly answered each item provides a useful picture of what South African learners know, and can do, in science. The following analyses – by content area, cognitive domain and question type – provide a profile of how learners answered each item.

Performance by content domain

The TIMSS 2003 science tests were designed to enable reporting on five content areas, in accordance with the TIMSS science framework. The five content areas (and % of items in the test) were:

- *Life sciences (30%).* This domain included understanding, amongst other elements, types, characteristics and classification of living things; structure, function and life processes in organisms; cells and their functions; and the development and life cycles in organisms.
- *Chemistry (15%).* This domain included classification and composition of matter; particulate structure of matter; properties and uses of water; acids and bases; and chemical change.
- *Physics (25%).* This domain included physical states and changes in matter; energy types, sources and conversions; heat and temperature; light; sound and vibration; electricity and magnetism; and forces and motion.
- *Earth sciences (15%).* This domain included earth's structure and physical features; earth's processes, cycles and history; and earth in the solar system and the universe.
- *Environmental sciences (15%).* This domain included changes in population, uses and conservation of natural resources, and changes in environments.

The content area scores were scaled to compare the relative performances. South Africa's performance in each of these areas is indicated in Table 6.6.

Relative to the other content areas, South African learners performed well in the chemistry domain. Performance was weakest in the physics and earth science domains.

Table 6.6: Relative science scale scores (and SE) in the content domains

Life sciences	Chemistry	Physics	Earth sciences	Environmental science
250 (6.0)	285 (5.9)	244 (6.2)	247 (6.3)	261 (6.6)

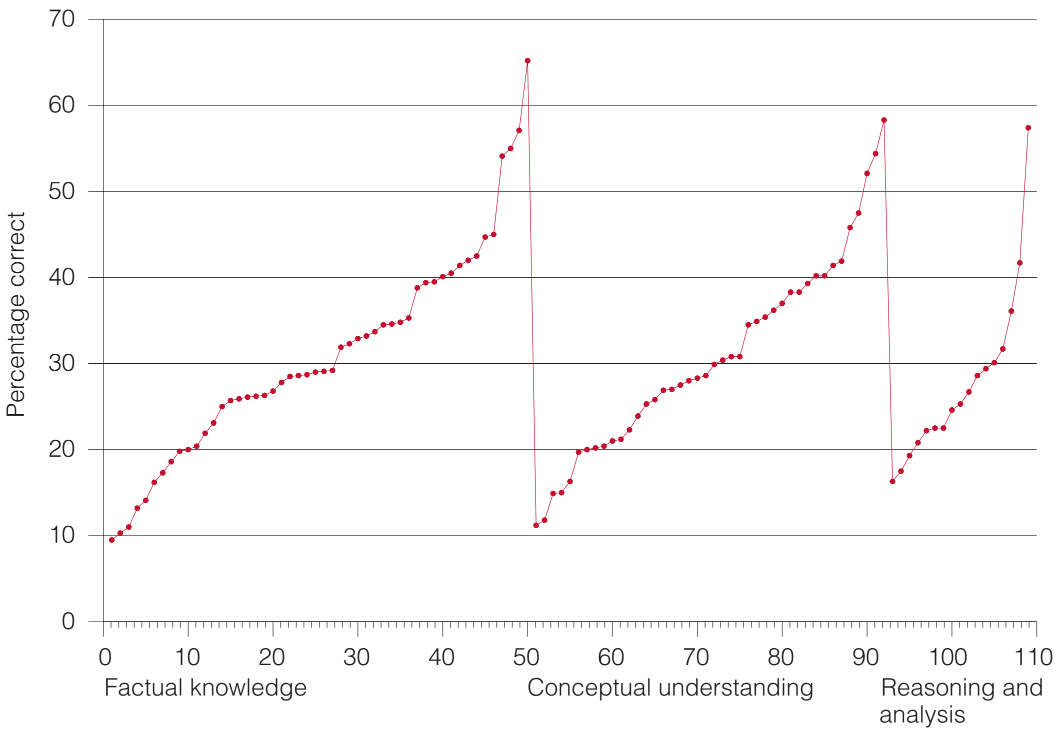
Performance by cognitive domain

The TIMSS 2003 science items were categorised into one of three cognitive domains. The cognitive domains define the behaviours expected of learners as they engage with the science content. The three cognitive domains (and % of items in the test) were:

- *Factual knowledge (30%).* This refers to the learners' knowledge base of relevant science facts, information, tools and procedures. In order to solve problems and develop explanations in science, learners must possess a strong knowledge base.
- *Conceptual understanding (35%).* This means having a grasp of the relationships explaining the physical world and relating the observable to more abstract, or general, scientific concepts.
- *Reasoning and analysis (35%).* A major purpose of science education is to prepare learners to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to encompass new situations.

Figure 6.6 provides a profile of how South African learners answered each MCQ item, categorised according to the three cognitive domains.

Figure 6.6: Percentage of learners who correctly answered items in each cognitive domain

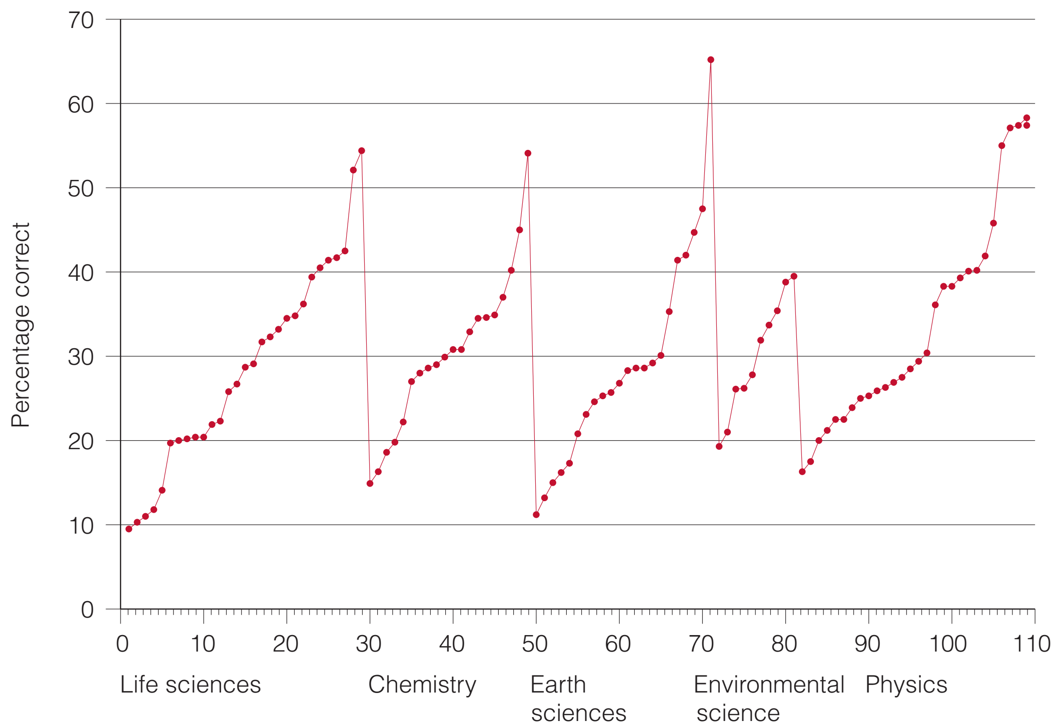


Although there is a hierarchical nature to the cognitive domains, with the factual knowledge domain considered to be at a lower cognitive level than the reasoning and analysis domain, the performance in each of the domains is similar, that is, there is a similar distribution of correct answers across the domains. In each of the cognitive domains, on most items, less than 40 per cent of the learners scored correctly. One would have expected a higher percentage correct on items in the factual knowledge and conceptual understanding categories. Therefore, performance in the reasoning and analysis domain is, relatively speaking, good.

Performance by question type

Learners' knowledge and understanding of science was assessed by MCQs and constructed-response questions. There were 110 MCQ items and 90 constructed-response items. The percentage of correct answers for the MCQ items ranged from 9.5 to 65.5 per cent. In the constructed-response questions, learners performed very poorly, with most of the items being answered correctly by less than 20 per cent of the learners. Figure 6.7 illustrates the percentage of learners correctly answering the MCQ items in the five content areas.

Figure 6.7: Percentage of learners who answered the MCQ items correctly



The graph shows that for most items less than 40 per cent of learners answered correctly. On only five MCQ items did more than half the learners respond correctly. Of the 110 MCQ items, in only eight items did more than half the learners answer correctly. The profile of learners' response rates for each of the content domains is similar.

Summary

From TIMSS 1999, there was a drop in the average age of learners who participated in TIMSS 2003. This implies that there is either less repetition, or fewer learners leave the system and then re-enter – suggesting that participation patterns are improving.

There is a difference in the performance of the country's provinces. The top three performing provinces were Western Cape, Northern Cape and Gauteng, and the three poorest performing provinces were KwaZulu-Natal, Eastern Cape and Limpopo. The score of the Western Cape is almost double the score of Eastern Cape. With the exception of Gauteng, there was an observable correlation between the provincial mathematics scale scores and the HDI rating.

Learners attending different school types achieved different average scores. Learners who attended ex-HoA schools achieved a score just above the international average. The average science scale score (and SE) for schools of the ex-racial departments were: ex-DET schools, 199 (SE = 3.9); ex-HoR schools, 311 (SE = 9.9); ex-HoD schools, 371 (SE = 26.3); and ex-HoA schools, 483 (SE = 17.3).

There was a decrease in the average score in ex-HoR schools (with the difference being 'not quite' significant) and ex-HoD schools in the period 1999 to 2003. There was an increase in average score in ex-DET (by 4 points) and ex-HoA schools (by 26 points), but none of the changes are statistically significant.

Nationally, the performance between girls and boys was similar, with the girls scoring 242 (SE = 7.2) and the boys scoring 264 (SE = 6.4). Provincially, there was also no gender difference in science performance.

Learners who answered the questions in English and Afrikaans achieved different average scores. Many learners who answered in English were not answering in their home language, and this may explain the lower score attained – 231, compared to 376 for learners answering in Afrikaans.

Learners answered relatively well in the domains of chemistry and environmental education. The lower performances were in the domains of physics and earth sciences.

Grade 9 mathematics and science achievement in TIMSS 2003

The South African school curriculum is based on a band qualification. There are four phases to the curriculum's structure: the foundation phase (Grades 1–3); intermediate phase (Grades 4–6); senior phase (Grades 7–9); and secondary phase (Grades10–12). The curriculum statements outline the topics for the band and the sequence of topics taught is decided by the class teacher.

The HSRC decided to administer the instruments to both Grade 8 learners (as per the requirements of TIMSS) and to Grade 9 learners to investigate whether the sequence of topics taught would make a difference to the performance. When the instruments were administered to Grade 8 learners, the same sample of schools was used to select a Grade 9 class. As in the Grade 8 classes, an intact Grade 9 class was randomly selected. Within that class unit, instruments were administered for two HSRC studies. Half the class (with learners randomly selected) took the TIMSS tests and the other half answered the instruments for a HSRC longitudinal study.

In the TIMSS Grade 9 study, 4 261 learners from 238 schools participated (see Appendix 4). There were fewer schools participating in the Grade 9 study compared to the Grade 8 study; this because the instruments were administered at a time of year when there were many other ongoing activities in the school (for example, getting ready for matric examinations and administering the Common Task of Assessment).

The results for the Grade 9 study closely paralleled the results of the Grade 8 study. This chapter provides a brief description of performance in mathematics and science.

Mathematics and science achievement scores at the Grade 9 level

The average mathematics and science scale scores for South African learners at the Grade 8 and 9 levels, and the average age of the groups, are indicated in Table 7.1.

Table 7.1: Table of average scores in mathematics and science for Grades 8 and 9

	Mathematics scale score (SE)	Science scale score (SE)	Average age
Grade 8 (n = 8 952)	264 (5.5)	244 (6.7)	15.1 yrs
Grade 9 (n = 4 261)	285 (4.2)	267 (5.4)	16.1 yrs
Difference between Grade 8 and 9 scores	21	23	

The performance on TIMSS 2003 at the Grade 9 level is still very low, even though there is a 20-point score improvement on Grade 8 in both subjects. Such a small improvement is disappointing. Given that these learners would have had an extra year's education, one assumes that they would perform at a much higher level than the Grade 8 learners – that they do not is cause for concern.

Performance by province

Table 7.2 indicates the average mathematics and science scale score for each of the provinces at the Grade 9 level, as well as the point difference between these results and the Grade 8 scores.

Table 7.2: Provincial mathematics and science Grade 9 scale scores and point difference to Grade 8 performance

Province	Mathematics		Science	
	Grade 9 average scale score (SE)	Difference to Grade 8 score	Grade 9 average scale score (SE)	Difference to Grade 8 score
Western Cape	414 (20.9)	25	421 (22.4)	35
Northern Cape	340 (17.8)	7	357 (18.3)	23
Gauteng	303 (10.9)	-1	301 (14.6)	-8
Free State	291 (13.1)	26	280 (15.4)	35
National average	285 (4.2)	21	267 (5.4)	23
Mpumalanga	287 (16.1)	26	266 (18.6)	27
KwaZulu-Natal	278 (11.7)	23	253 (13.4)	26
North West	280 (11.9)	29	260 (15.1)	29
Eastern Cape	250 (10.4)	27	222 (13.5)	32
Limpopo	244 (6.8)	27	216 (9.4)	25

The rank order of provincial scores for mathematics and science at the Grade 9 level mirrored the rank order at the Grade 8 level. In most provinces there was a score increase of around 25 points from Grade 8 to Grade 9. The surprising result was Gauteng, which registered a decrease in both the mathematics and science scores.

Performance at the different benchmarks

The scores of the Grade 9 learners were categorised at the different performance benchmarks to provide a picture of the number of learners achieving the higher scores. For mathematics, 9.6 per cent of the learners achieved scores higher than 400; for science 12.4 per cent of learners achieved this. These results were similar to the results for Grade 8. Again, it is of concern that the Grade 9 learners achieved at the same level as the Grade 8 learners – one would have expected them to attain higher scores.

Participation and performance by gender

There were almost equal numbers of girls and boys in the TIMSS Grade 9 sample (50.6 per cent girls and 49.4 per cent boys). The average scale scores of the boys in mathematics and science was a few points higher, but this difference is not statistically significant.

Table 7.3: Performance of girls and boys in mathematics and science at Grade 9 level

	Girls	Boys	Difference: boy–girl score
Science scale score (SE)	261 (7.0)	274 (6.1)	13
Mathematics scale score (SE)	283 (5.4)	287 (5.4)	4

Performance by ex-racial department of schools

The average scale scores for mathematics and science for schools classified by the ex-racial departments was calculated in the same manner as the Grade 8 study. Table 7.4 indicates the achievement scores in mathematics and science by the different school type.[1]

Table 7.4: Average mathematics and science scale scores of learners from the different school types

	Average science scale score (SE)	Average mathematics scale score (SE)
Ex-DET schools (n = 3 314)	234 (4.4)	257 (2.8)
Ex-HoR schools (n = 496)	345 (10.1)	339 (8.0)
Ex-HoD schools (n =137)	380 (23.5)	373 (18.0)
Ex-HoA schools (n = 314)	512 (17.0)	499 (16.6)
National average (Grade 9)	267 (5.4)	285 (6.5)

As at the Grade 8 level, the average scores for the ex-HoA schools were the highest, followed by scores for ex-HoD and ex-HoR schools. The average score for the ex-DET schools was the lowest.

Performance by content area

The average scale scores of learners in the science and mathematics content areas were calculated. These scale scores are provided in Tables 7.5 and 7.6.

Table 7.5: Relative mathematics scale scores (and SE) in the content domains

Number	Algebra	Measurement	Geometry	Data
283 (4.5)	284 (4.1)	305 (4.1)	257 (5.3)	312 (4.0)

As at the Grade 8 level, the Grade 9 learners performed best on measurement and data and were weakest in geometry.

1 The sample size for the ex-HoR, ex-HoD and ex-HoA schools are not adequate for providing a score representative of this category of schools. These scores should be considered as indicative.

Table 7.6: Relative science scale scores (and SE) in the content domains

Life science	Chemistry	Physics	Earth science	Environmental science
277 (5.2)	287 (4.7)	269 (5.2)	253 (5.2)	294 (5.7)

Relative to the other content areas, the Grade 9 learners performed better on questions relating to environmental science and chemistry, while the weakest performance was in the physics domain. A similar pattern was observed at the Grade 8 level.

Summary

The Grade 9 performance in mathematics and science mirrors the Grade 8 performance. A disappointing feature of the results is that the average scores for Grade 9 learners are only around 20 points higher than the Grade 8 scores.

CHAPTER 8

The social, educational and curriculum landscape

Introduction

Chapters 3, 4, 5 and 6 considered the mathematics and science performance of Grade 8 learners within both national and international parameters. To provide an insight into the meaning of the achievement scores and postulate hypotheses for this performance, these scores need to be read against the social, educational and curriculum landscape of South Africa. This Chapter will first briefly describe some aspects of the social and educational landscape. This will be followed by a detailed description of the curriculum changes occurring since 1994. Information gathered on the curriculum from teacher questionnaires and the curriculum itself will then be presented.

Social landscape

Apartheid in South Africa came to end with the democratically held elections of 1994. South African society is, however, still characterised by high levels of poverty and enormous inequality – unwelcome legacies of the apartheid era. The latest UNDP report (2005) estimates that at least one-third of the population is living on less than $2 a day, with 11.1 per cent living on less than $1 a day. The Gini coefficient, which measures (among other things) national income distribution, was 0.6 in 2000.[1] This demonstrates that South Africa (along with Brazil) has one of the most unequal income distributions in the world (Statistics South Africa 2002). Africans, still struggling with the harsh consequences of apartheid rule, represent the poorest group. In the field of education, African schools endure crippling backlogs in the provision of basic infrastructure, learning materials and qualified teachers, all of which affect science and mathematics participation and achievement.

In the last ten years the government has attempted to improve the infrastructure and resources in schools previously designated for Africans. However, this is, 'unfolding at a much slower pace than envisaged' (Mbeki 2005). Twenty-five per cent of schools (mostly African) do not have access to running water and about 45 per cent do not have access to electricity (DoE 2001). African schools are still located in the areas designated for Africans to live in by the previous government, and these continue to be the poorest areas of the country.

South Africa has nine provinces and differences exist between them. Provincial performance on key socio-economic indicators is provided in Appendix 6, where information on indicators such as poverty rate, life expectancy, unemployment rate, and access to electricity, water and sanitation is given.

1 The Gini coefficient is a number between 0 and 1, where 0 equates to perfect equality (where everyone has the same income) and 1 corresponds with perfect inequality (where one person has all the income, and everyone else zero income). South Africa's 0.6 rating therefore represents, as noted, a markedly unequal national income distribution. Source: http://www.en.wikipedia.org/wiki/Gini_ coefficient.

Educational landscape

In 2002, the South African public school system consisted of 28 000 ordinary schools, 356 000 educators and 12 million learners. Since 1994, there have been many changes in South African education. According to the DoE (2005) the first phase of the post-apartheid change in the education and training system – 1994–1999 – was concerned with the system's reconstruction. This meant creating a single national system with nine provincial sub-systems, introducing nine year compulsory schooling, establishing school governing bodies, consolidating the teaching service, establishing a National Qualifications Framework, and introducing the outcomes-based Curriculum 2005.

This first phase involved systemic changes which resulted in the policy, legislation, protocols, structures and systems being put in place. The second phase, from 1999, has been characterised by a focus on implementation of policies. The debate in education shifted from issues of access and participation to focus on the quality of teaching and learning processes and inputs at the local level. Attention was directed towards sustaining learner participation through improving the quality of education in the institutions. Greater effort was made to improve opportunities for the poorest learners and communities in the system. Interventions during this period included upgrading and developing teachers' skills and implementing a revised curriculum for schooling.

Learners attend school for 12 years – in the General Education and Training (GET) section (Grades 1 to 9) and the Further Education and Training (FET) section (Grades 10 to 12). GET, which is compulsory, is organised into three phases: foundation (Grades 1 to 3), intermediate (Grades 4 to 6), and senior (Grades 7 to 9). South Africa's national Ministry of Education is responsible for the development of the policies and frameworks for education and the curriculum. The provincial ministries of education are responsible for the implementation and support of these policies.

Mathematics and science are two key areas where skills and competence are essential, not only for the development of the individual (that is, the learner), but also for the social and economic development of South Africa in a globalising world. Since 1994, the new democratic government has emphasised the centrality of mathematics and science to the human development strategy of South Africa (Mbeki 2001, 2005). The local government, business, academic and family sectors of the country have likewise acknowledged that South Africa's well-being cannot be developed without heavy investment in the scientific and mathematic disciplines. Recognition of the disadvantaged condition of the African population has also been apparent over the past decade; so too the need for programmes of redress to ensure better participation and performance in mathematics and science for the African community. Commitment to this has been outlined in various government gazettes and policy documents (DoE 1996; DoE & DoL 2000; DST 2002). These policies affirm that to build the mathematic, scienctific and technological capacity of South Africa requires intervention at the school level. This is the only way to meet the demands of the higher education and workplace environments and to ensure broader, more equitable participation in these sectors.

The DoE has developed a national strategy to improve participation and performance in mathematics and science education (DoE 2001). The flagship programme in the strategy was the Dinaledi project. This project centred on the identification and selection of schools in each of the country's provinces that exhibited the potential to perform well (and, therefore, to raise mathematics and science participation and performance).

The schools (102 in total) received additional facilities, equipment and support for the provision of effective mathematics and science teaching and learning. While the Dinaledi vision of investing in potentially successful schools appears sound, there have been problems in the selection of schools according to the pre-determined criteria; in addition, the implementation of the interventions in the schools has been uneven. The Dinaledi intervention has yet to be independently evaluated. Furthermore, the project has still to demonstrate the gains in participation and performance that were originally anticipated. In 2005, the Dinaledi initiative increased the number of schools in the programme to approximately 500.

South Africa has participated in a number of large-scale systemic studies assessing the performance of the country in science and mathematics (these having been conducted by international and national agencies).The DoE's systemic evaluation at the Grade 3 level revealed that the national average score for numeracy was 30 per cent (DoE 2002a). In the UNESCO-co-ordinated MLA studies for Grade 4 learners; the average numeracy score for South Africa was 30 per cent, compared to 59 per cent for Mauritius, 40 per cent for Senegal, and 43 per cent for Malawi (Chinapah et al. 2000). In 2004, the DoE's Grade 6 systemic study revealed the average mathematics score as 27 per cent and the average science score as 41 per cent.

While there has been noticeable commitment to mathematics and science education from various sectors, the achievements in these areas are still poor. The country is still grappling with how to improve the quality of school education and achieve higher learner performances.

Curriculum landscape

In the last decade there has been large-scale and radical curriculum reform in South Africa. In the old curriculum (NATED 550) all learners took general science and mathematics up to the end of Grade 9. In Grade 10, learners could choose to enrol for mathematics, physical science or biology. This curriculum was content-driven and the content to be taught was specified for teachers.

A new curriculum was prepared for the country. In 1998, C2005, based on an outcomes-based education (OBE) philosophy, was introduced by phases into schools. The intention was that by 2005 the whole schooling system would follow an OBE approach. The OBE curriculum necessitated a major shift in the approach to teaching, leading to a planned set of in-service activities for teachers, together with the development of learning materials. However, the process of implementation was hampered by lack of resources (financial, physical and human). The new curriculum was not well received by teachers and academics and there were widespread protests. Published research also commented on the difficulties of implementing this new curriculum.

The new curriculum was criticised for its under-specification of content and lack of structured resourced materials for teachers, brought about by the programme's departure from a traditional, content-based approach. In addition, it was perceived there was an overemphasis on the processes involved in science and mathematics and an underemphasis on basic knowledge and skills. During this period, because of the under-specification of content and lack of teaching materials, teachers then fell back on teaching the content that they had done previously (that is, under the NATED 550 curriculum). Chisholm et al. (2000, 2003) outlines the process, concerns, debates and critiques of

C2005. In 2000, the Minister of Education requested advice on the implementation of the new curriculum and set up a Review Committee to consider the feasability of its introduction and application. However, the establishment of the Review Committee served to cause confusion in the teaching community – teachers were uncertain whether OBE had been abandoned or not, and so fluctuated between using C2005 as a guide and following the previous curriculum.

The Review Committee submitted their findings to the Minister in May 2000 and recommended a revision of Curriculum 2005. This led to a process of streamlining and strengthening the curriculum and, in 2002; the Revised National Curriculum Statements (RNCS) were produced. The RNCS were to be implemented, in a phased manner, from 2004. The Revised National Curriculum Statements (DoE 2002b) provided a better structure for teachers to organise their classroom activities under. From 2002, especially at the higher grades, teachers used the three curriculum documents (NATED 550, Curriculum 2005 and the RNCS) and textbooks to decide what and how to teach in their classroom. Unfortunately, this resulted in a significant variation in what was taught in mathematics and science across the different classrooms in the country – making it difficult to isolate and define the intended curriculum.

The rapid and frequent restructuring of the education curriculum over a short period of time has caused uncertainty and anxiety among teachers, who are unsure about policy changes and which policy applies at a particular time. Teachers have attended many professional development activities (mostly during school time) to prepare them for the latest changes and this has led to losses in teaching time.[2] In the short term, the new curriculum may have negatively affected learners' knowledge, a situation caused by teachers struggling to understand the new outcomes-based approach and then teaching it using unfamiliar learning materials

TIMSS curriculum analysis

TIMSS administered a curriculum questionnaire that the national research co-ordinators were required to complete. One question regarded determining the proportion of Grade 8 learners who would have been taught the different curriculum topics by the end of the Grade 8 year. Because of the various curriculum changes occuring over the period in which TIMSS was conducted, it was difficult to 'pin down' the curriculum in the questionnaire. C2005 indicated that the content would not be prescribed and that teachers could choose what content to teach – it was more important to ensure that the learning outcome had been achieved.

Interviews with teachers, DoE officials and academics about the content selection for Grade 8 mathematics and science revealed the use of different sets of procedures in determining content areas. Some interviewees followed examples provided at in-service courses; others followed what was covered in the previous (pre-1994) curriculum; some followed the content in a textbook. Therefore, in the reporting that follows for the South African curriculum, it was decided to utilise what the teachers reported in the teacher questionnaires. In other countries, where official documents are more likely to be universally applied and followed, this strategy would not be needed.

2 For further details, refer to Chisholm 2005 which was commissioned by the Education Labour Relation Council.

Description of the South African science and mathematics curriculum

Science curriculum

In the new curriculum, at the General Education and Training (GET) phase (Grades 1 to 9), natural science is compulsory for all learners. Learners begin their science studies in Grade 4 and from Grades 4 to 6 follow a natural science and technology curriculum. From Grades 7 to 9 they take the subject natural science. This subject is compulsory for all learners up to Grade 9. natural science is offered for 12 per cent of the instructional time in the Grade 7 to 9 band (the senior phase).

Education systems use different ways to achieve the best match between the *intended* and the *implemented* curriculum. Internationally, the most widely used methods for supporting and monitoring curriculum implementation reported by education ministries were: provision of instructional or pedagogical guides (47 TIMSS participants); education ministry notes and directives (40 TIMSS participants); school inspection or audit (38 participants); mandatory or recommended textbooks (38 participants); curricular evaluation during or after implementation (35 participants); and the use of specially developed or recommended instructional activities (33 participants). The least widely used method was national assessments on learner samples (21 participants).

To support the implementation of the new curriculum, the South African Ministry of Education indicated that they provided instructional or pedagogical guides, notes and directives. However, according to Curriculum 2005, schools and teachers were not provided with recommended textbooks – rather, teachers developed their own set of learning support materials from a range of resources. On balance, it would seem that many of the TIMSS participating countries offered schools and teachers much more structured guidance (in the form of guides, notes and textbooks) than the South African Ministry of Education.

Different curricula emphasise different approaches and processes in the intended science curriculum. Internationally, the processes emphasised 'a lot' were: knowing basic science facts (35 countries); understanding scientific concepts (34 participants), and writing explanations on what was observed and why it happened (20 participants). By way of contrast, South African policy-makers indicated that in Curriculum 2005 there was 'some emphasis' on: knowing basic science facts; understanding scientific concepts; designing and planning experiments and investigations; conducting experiments or investigations; learning about the nature of science and inquiry; and understanding human impact on the environment. There was 'a lot of emphasis' on: integrating science with other subjects; learning about technology and its impact on society; and incorporating the experiences of different cultural/ethnic groups. Internationally, relative to the other approaches and processes, participants reported placing less emphasis on integrating science with other subjects and incorporating the experiences of different ethnic/ cultural groups. Four participants (Botswana, Israel, Italy and South Africa) reported placing a lot of emphasis on integrating science, and two countries, South Africa and Sweden, reported placing 'a lot of emphasis'on the multicultural approach when using the intended curriculum.

These findings highlight a major difference between South Africa's approach to the curriculum and that of most other countries. Whereas South Africa places 'a lot of emphasis' on integrating science and incorporating the experiences of different groups, most other countries put 'a lot of emphasis' on understanding science concepts and knowing basic facts.

To gather information about the implemented curriculum on science coverage in the classroom, science teachers were asked to indicate whether each of the TIMSS 2003 science topics was 'mostly taught before this year'; 'mostly taught this year'; or, 'not yet taught or just introduced'. Table 8.1 shows the response for South Africa averaged across the content areas, as well as a scaled international score for a global comparison.[3]

Table 8.1: Summary of percentage of learners taught the TIMSS science topics, and the average scale scores for each content area

	Overall (44 topics)	Life science (12 topics)	Chemistry (8 topics)	Physics (10 topics)	Earth science (11 topics)	Environmental science (3 topics)
South Africa	49%	57%	54%	46%	37%	63%
	244 (6.7)	250 (6.0)	285 (5.9)	244 (6.2)	247 (6.3)	261 (6.6)
International	67%	70%	70%	66%	61%	49%
	474 (0.6)	474 (0.5)	474 (0.5)	474 (0.5)	474 (0.5)	474 (0.5)

For most countries, a great deal of the science content addressed by the TIMSS 2003 assessment was included in their intended curriculum. In only eight countries were less than half the topics included in the Grade 8 curriculum: Belgium, Botswana, Cyprus, Indonesia, Lebanon, Morocco, South Africa and Tunisia. For South Africa, as one of these eight, the content area in which there was the greatest overlap with the TIMSS assessment frameworks was environmental science, and the content area with the least overlap is earth science. The corresponding achievement scores indicate South African learners performing best in chemistry (where there is 54 percent overlap) and weakest in physics (where there is 46 percent overlap).

While high coverage of the intended curriculum is important for higher performance, the relationship is not as straightforward as it may appear. There are some countries with low curriculum coverage that performed well (for example, Belgium). However, countries such as Botswana, Indonesia, Morocco and South Africa, all of whom indicated low curriculum coverage, attained low achievement scores. In addition to providing scale scores, TIMSS calculated the average percent correct for the items in TIMSS 2003. This statistic provides a better indication of what learners know. For South Africa, the average percent correct for all items in the science test was 19 per cent. To determine how performance is affected by curriculum coverage, TIMSS conducted a test curriculum matching analysis (TCMA), where the average percentage correct was calculated for those items that teachers indicated had been taught in the South African curriculum. South Africa achieved a 22 per cent success rate for items that were covered in the country's curriculum – still a low performance.

3 The complete description of performance in each of the topic areas is available in the international report.

Mathematics curriculum

Grade 8 South African learners have, since 2002, studied mathematical literacy, mathematics and mathematical sciences (MLMMS). They begin a study of numeracy in Grade 1 and follow a MLMMS curriculum from Grade 4. This subject is compulsory for all learners up to Grade 9. MLMMS is offered for 13 per cent of the instructional time in the Grade 7 to 9 band (the senior phase).

Education systems use different ways to achieve the best match between the *intended* and the *implemented* curriculum. Internationally, the most widely used methods for supporting and monitoring curriculum implementation reported by education ministries were: education ministry notes and directives (42 TIMSS participants); provision of instructional or pedagogical guides (41 TIMSS participants); school inspection or audit (40 participants); mandatory or recommended textbooks (38 participants); curricular evaluation during or after implementation (35 participants); and the use of specially developed or recommended instructional activities (33 participants). The least widely used method was national assessments on learner samples (25 participants).

To support the implementation of the new curriculum, the South African Ministry of Education indicated that they provided instructional or pedagogical guides, notes and directives. However, according to Curriculum 2005, schools and teachers were not provided with recommended textbooks – rather, teachers developed their own set of learning support materials from a range of resources. On balance, it would seem that many of the TIMSS participating countries offered schools and teachers much more structured guidance (in the form of guides, notes and textbooks) than the South African Ministry of Education.

Different curricula emphasise different approaches and processes in the intended mathematics curriculum. Internationally, the processes emphasised ‘a lot’ were: understanding mathematical concepts and principles (32 participants), and mastering basic skills (30 participants). By way of contrast, South African policymakers indicated that in Curriculum 2005 there was ‘some emphasis’ placed on: mastering basic skills; understanding mathematical concepts and principles, and reasoning mathematically. There was, ‘a lot of emphasis’ on: applying mathematics to real- life situations; communicating mathematically; integrating mathematics with other subjects; and incorporating the experiences of different cultural/ethnic groups. There was no emphasis on deriving formal proofs. Internationally, relative to the other approaches and processes, participants reported placing less emphasis on integrating mathematics with other subjects and incorporating the experiences of different ethnic/cultural groups. Three participants (Botswana, the Netherlands, and South Africa) reported placing a lot of emphasis on applying mathematics to real-life situations. Two countries, Ghana and South Africa, reported placing ‘a lot of emphasis’ on the multicultural approach when using the intended curriculum.

These findings highlight a major difference between South Africa’s approach to the curriculum and that of most other countries. Whereas South Africa places, ‘a lot of emphasis’ on applying mathematics to real-life situations and multicultural approaches, most other countries put ‘a lot of emphasis’ on understanding mathematical concepts and principles and mastering basic skills.

To gather information about the implemented curriculum on mathematics coverage in the classroom, mathematics teachers were asked to indicate whether each of the TIMSS 2003 mathematics topics was 'mostly taught before this year'; 'mostly taught this year'; or, 'not yet taught or just introduced'. Table 8.2 shows the response for South Africa averaged across the content areas, as well as a scaled international score for a global comparison.[4]

Table 8.2: Summary of percentage of learners taught the TIMSS mathematics topics and the average scale scores for each content area

	Overall (45 topics)	Number (10 topics)	Algebra (6 topics)	Measurement (8 topics)	Geometry (13 topics)	Data (8 topics)
South Africa	55%	77%	57%	49%	48%	40%
	264 (5.5)	274 (5.4)	275 (5.1)	298 (4.7)	247 (5.4)	296 (5.3)
International	72%	95%	66%	78%	69%	46%
	467 (0.5)	467 (0.5)	467 (0.5)	467 (0.5)	467 (0.5)	467 (0.5)

For most countries, a great deal of the mathematics content addressed by the TIMSS 2003 assessment was included in their intended curriculum. In only six countries were less than half the topics included in the Grade 8 curriculum: Botswana, Indonesia, Lebanon, Morocco, the Philippines, and Tunisia.

In South Africa, 55 per cent of the topics which were in the TIMSS assessment was covered in classrooms. The content area where there was the greatest overlap with the TIMSS assessment frameworks was number (77 per cent), and the content area with the least overlap was data (40 per cent). South African learners performed best in the content area of measurement, where 49 per cent had been taught all topics, while the poorest performance was in the area of geometry, where 48 per cent of learners had been taught all the topics.

While high coverage of the intended curriculum is important for higher performance, the relationship is not as straightforward as it may appear. There were some countries with low curriculum coverage that performed well (for example, Belgium). In addition to providing scale scores, TIMSS calculated the average percent correct for the items in TIMSS 2003. This statistic provides a better indication of what learners know. For South Africa, the average percent correct for all items in the mathematics test was 17 per cent. To determine how performance is affected by curriculum coverage, TIMSS conducted a test curriculum matching analysis (TCMA), where the average percent correct was calculated for those items that teachers indicated had been taught in the South African curriculum. South Africa achieved an 18 per cent success rate for items that were covered in the country's curriculum – still a low performance.

4 The complete description of performance in each of the topic areas is available in the international report.

Summary

South African society is highly stratified. Amongst the disadvantaged groups, Africans experience the highest levels of poverty. The new education system, introduced in 1994, has undergone many changes. Since 1997, there have been curriculum changes and the introduction of an outcomes-based education policy. The TIMSS assessment revealed that teachers were often uncertain regarding exactly what curriculum they should be implementing. Furthermore, the official curriculum in 2002, C2005, was characterised by (and criticised for) under-specification of basic knowledge and skills.

The South African curriculum is also one where, when compared internationally, there is the least overlap with the TIMSS assessment frameworks. This might have been anticipated to have an effect on the achievement scores. However, an analysis of performance on topics teachers indicated they *had* covered demonstrated that performance was still very poor: learners achieving only around 20 per cent correct on those items.

CHAPTER 9

South African TIMSS learner profiles

Introduction

The background characteristics of learners play an important role in understanding learner achievement. To study the effect of learner characteristics, learners answered a 30-minute questionnaire giving background information on themselves.

This chapter uses information from these questionnaires to describe the South African Grade 8 TIMSS population and explore the association between learners' backgrounds and achievement scores. The chapter will include learner demographic characteristics, home background (learning resources at home, educational level of parents, and language of the home), and attitudes of learners (towards mathematics and science). In addition, comparative statistics on these factors for two other African countries (Botswana and Ghana) and two top-performing countries (Singapore and Norway) will be provided. The across-country analysis, encompassing a diversity of learners displaying similar characteristics, can be useful in generating or excluding hypotheses that might influence learner achievements. In the learner descriptions, statistics on indicators linked to the above – and the corresponding achievement scores – are included. Where the statistics between mathematics and science are comparable, only the mathematics statistics are used.

TIMSS is based on the assumption that home background factors influence achievement, and the type of background information collected is influenced by this. It has been argued that this applies more readily to richer countries (for example, see Fuller 1986). In poorer countries, many learners come from homes with little financial or educational resources. In these circumstances, the school plays the major role in influencing educational outcomes. However, it is still useful to describe learner characteristics as this provides a context for understanding achievement.

Demographic characteristics

Gender

In the South African sample there were almost equal numbers of boys and girls. This was also the pattern in all the provinces, except Eastern Cape and Gauteng where about 8 per cent more girls than boys participated.

Table 9.1: Participation rates by gender, and average age of TIMSS learners by province

	WC	NC	G	FS	M	NW	KZN	L	EC	Nat.
Girls (%)	49.9	48.5	54.3	49.0	49.7	51.5	50.3	50.5	53.9	49.3
Boys (%)	50.1	51.5	45.6	51.0	50.3	48.5	49.7	49.5	46.1	50.5
Sample size	775	866	732	867	962	945	1 631	1 143	921	8 840*
Average age (years)	14.6	14.8	14.8	15.4	15.2	15.3	15.0	14.9	15.5	15.1

*Notes: * This number is slightly lower than the total number of cases because some learners did not indicate their gender.*
WC = Western Cape; NC = Northern Cape; G = Gauteng; FS = Free State; M = Mpumalanga; KZN = KwaZulu-Natal; NW = North West; EC = Eastern Cape; L = Limpopo.

Age

The average age of the national sample was 15.1 years and the age of the provincial sample ranged from 14.6 to 15.5 years. Provinces where the average age was above the national average were Mpumalanga (15.2), North West (15.3), Free State (15.4), and Eastern Cape (15.5).

Racial profile of learners in different types of schools

TIMSS 1999 data was collected in 1998 and TIMSS 2003 data in 2002. During this period, the racial composition of school learners changed. In both studies, learners were asked, in the learner questionnaires, to indicate their racial classification, but this could not be corroborated from other sources.[1] Table 9.2 indicates the racial composition of learners in the different school types. The unsubstantiated nature of the information, together with the small sample size in the ex-HoA, ex-HoR and ex-HoD schools, means these percentages should be considered as indicative rather than representative.

Table 9.2: Racial composition of learners in the TIMSS sample, by school type

	Races	Grade 8 in 1998	Grade 8 in 2002
National sample	African	75.7%	74.8%
	Coloured	13.0%	13.5%
	White	8.7%	8.3%
	Indian	2.6%	3.4%
Ex-DET	African	98.5%	96.1%
	Coloured	0.7%	2.4%
	White	0.4%	0.3%
	Indian	0.5%	1.1%
Ex-HoR	African	5.8%	43.3%
	Coloured	92.6%	56.0%
	White	0.4%	0.2%
	Indian	1.2%	0.5%
Ex-HoD	African	41.5%	54.0%
	Coloured	2.4%	3.2%
	White	0.5%	0.0
	Indian	55.6%	42.8%
Ex-HoA	African	18.9%	34.6%
	Coloured	12.7%	17.0%
	White	67.4%	47.2%
	Indian	1.0%	1.1%

1 Although the notion of racial discrimination is now legal history in South Africa, it is not always possible to guage the effects of past practices, and the progress of policies designed to eradicate them, without some reference to population groups. For this reason, the HSRC continues to use the terms black/African, white, coloured and Indian/Asian where this is pertinent to the analysis of data.

There has been a migration of learners from ex-DET, ex-HoR and ex-HoD schools to ex-HoR, ex-HoD and ex-HoA schools. There has been almost no migration of learners from the other departments to the ex-DET schools, where the learner population is almost entirely African. Most of the African, Indian and coloured learners who have moved to the ex-HoA schools would have to be financially better resourced to afford the school fees and other opportunity costs. In each of the ex-HoR, ex HoD and ex-HoA school types, there has been an increase in the number of African learners attending these schools.

Home background

Home background provides an insight into learners' social and economic capital. The past IEA assessments (PIRLS and TIMSS) have demonstrated that in most countries, learners from homes with extensive educational resources have higher achievement scores than learners from less advantaged backgrounds. In this analysis there is a focus on the following variables: parental education; the number of books at home; the language spoken in the home. The associated achievement scores are also provided.

Parents' education

Parents are important educators in the lives of their children and can be an important educational resource in the home. Learners were asked to indicate the highest level of education attained by their parents. Table 9.3 displays the percentage of parents at the different educational levels (the parent with the higher education was chosen) and the corresponding average mathematics scale scores (and SE).

Internationally, learners had difficulty answering the question about their parents' education level. In South Africa, between 70–85 per cent of the learners responded to the question. Countries reporting the highest percentage (greater than 40 per cent) of

Table 9.3: Highest educational level of either parent and average mathematics scale scores

	Finished university or equivalent or higher	Finished post- secondary (not university)	Finished upper secondary	Finished lower secondary	Finished primary
South Africa	11%	13%	30%	18%	28%
	352 (16.6)	294 (10.0)	266 (6.0)	244 (4.0)	223 (4.4)
Botswana	10%	14%	16%	20%	41%
	411 (7.1)	378 (4.0)	361 (4.0)	366 (3.5)	356 (3.0)
Ghana	10%	17%	22%	37%	14%
	320 (8.1)	296 (6.7)	292 (5.8)	261 (5.7)	246 (5.5)
Singapore	16%	4%	21%	48%	11%
	651 (3.3)	624 (5.9)	621 (3.6)	600 (3.9)	571 (6.0)
Norway	66%	16%	12%	4%	2%
	485 (2.6)	459 (5.7)	451 (4.9)	419 (9.4)	2 (–)
International average	28%	17%	28%	15%	12%
	503 (0.9)	480 (0.9)	463 (0.7)	434 (1.1)	410 (1.4)

university-educated parents included Armenia, Estonia, Israel, Japan, Norway, the Russian Federation, and the USA. Countries reporting the highest percentage (greater than 40 per cent) of parents with no more than primary education included Botswana, Iran, Morocco, Saudi Arabia and Tunisia. The difference in achievement scores between children whose parents have completed university education and those with no more than primary education is around 90 internationally. This difference, however, varies from country to country. In South Africa the difference is 129 (the largest); in Botswana it is 55, in Ghana it is 74, and for Singapore it is 80.

Within a country there is an association, as expected, between higher educational levels of parents and achievement scores. Across countries, however, learners with the same background characteristics attain different achievement scores. For example, 11 per cent of South African learners have parents with a university qualification and these learners attained a mathematics achievement score of 352. In Botswana, 10 per cent of the learners have a parent with a university qualification and they attained a mathematics score of 411. In Singapore, 16 per cent of learners have parents with a university education and their average score was 651. These differences in across-country scores suggest that there may be other factors, interacting with the issue of parents' education, which produce the learner achievement scores.

Home education resources

Past IEA studies have shown that learners from homes with extensive literacy resources attain achievement levels higher than those from less advantaged backgrounds. The number of books in the home is used as an indicator of the educational capital in the home. The profile of learners indicating the number of books that they have, and their corresponding average mathematics score (and SE), is shown in Table 9.4.

In countries such as Australia, Estonia, Hungary and Sweden, over 30 per cent of the learners reported that they had more than 200 books in their home. On the other hand, in countries such as Botswana, Egypt, Ghana, Iran, Morocco, Philippines and South Africa, more than 30 per cent of the homes have 10 books or less. In fact, Botswana,

Table 9.4: Number of books in the home and average mathematics score

	200+ books	101–200 books	26–100 books	11–25 books	0–10 books
South Africa	6%	5%	14%	31%	44%
	324 (17.5)	325 (19.5)	304 (11.7)	261 (5.0)	241 (3.1)
Botswana	4%	5%	13%	30%	48%
	401 (12.5)	400 (6.9)	386 (5.8)	368 (4.1)	355 (2.6)
Ghana	10%	6%	16%	34%	34%
	275 (7.2)	300 (9.6)	294 (7.8)	285 (6.0)	264 (4.7)
Singapore	14%	16%	33%	24%	12%
	642 (3.5)	627 (3.7)	617 (3.2)	580 (5.1)	554 (5.2)
Norway	27%	22%	33%	11%	7%
	481 (3.2)	477 (3.1)	460 (3.0)	425 (4.2)	408 (7.2)
International average	15%	13%	27%	26%	18%
	498 (1.0)	492 (1.0)	476 (0.6)	449 (0.7)	429 (1.0)

South Africa and Palestinian National Authority are countries where more than 40 per cent of the homes have 10 books or less. Internationally, and in South Africa, the difference in mathematics achievement score between learners who have a large number of books at home and those who have a few books is around 80 score points. The South African achievement score, for both mathematics and science, of learners with more than 100 books (classifiable as a good set of educational resources) is still lower than Botswana, and considerably lower than the international mean.

Home languages

International assessment studies have shown that in countries where a large proportion of learners are from homes where the language of the test (and thus the language of teaching and learning in school) is not spoken at home, the mathematics and science achievement scores are generally lower. However, it is important when studying the effect of language to consider socio-economic factors, as these compound the impact on learner achievement scores. In the TIMSS learner questionnaire, learners were asked (on a four-point scale) to answer the question, 'How often do you speak the language of the test at home?'.Table 9.5 depicts the learners' responses. Since science teaching and learning is more dependent on language proficiency, the percentage response rates are shown separately for each subject.

Table 9.5: Extent to which the language of the test is spoken at home and mathematics and science average scores

		Always	Almost always	Sometimes	Never
South Africa		18%	9%	57%	15%
	Maths	349 (14.6)	319 (13.0)	247 (3.1)	192 (3.9)
	Science	347 (17.3)	310 (13.8)	225 (4.3)	153 (5.2)
Botswana		5%	6%	80%	9%
	Maths	375 (10.3)	402 (8.0)	367 (2.6)	329 (6.2)
	Science	374 (13.5)	412 (10.9)	366 (2.5)	316 (6.5)
Ghana		23%	10%	63 %	5%
	Maths	272 (5.3)	295 (8.7)	285 (4.6)	189 (12.2)
	Science	260 (7.0)	279 (10.9)	263 (5.8)	155 (11.5)
Singapore		23%	19%	49%	8%
	Maths	625 (3.8)	620 (3.5)	595 (4.3)	581 (5.7)
	Science	613 (3.9)	603 (3.9)	557 (5.1)	545 (6.7)
Norway		85%	10%	3%	1%
	Maths	463 (2.4)	463 (5.2)	427 (8.8)	–
	Science	498 (1.9)	489 (6.1)	435 (10.6)	–
International average		68%	11%	17%	4%
	Maths	472 (0.7)	477 (1.0)	441 (1.4)	396 (2.0)
	Science	482 (0.8)	483 (1.0)	442 (1.5)	389 (2.4)

Note: A dash (–) means that there is insufficient data to report achievement.

Internationally, 21 per cent of the learners were from homes where the language of the test is only spoken ‘sometimes’ or ‘never’. Countries where a large number of learners speak the language of the test infrequently at home include Botswana, Ghana, Indonesia, Lebanon, the Philippines, Singapore and South Africa. As expected, in each of the participating countries the learners who ‘always’ speak the language of the test at home score higher than learners who ‘never’ speak the language of the test at home.

However, the interesting analysis is the across-country scores for the groups who have indicated similar language proficiencies. The difference in the international average mathematics score between learners who ‘always’ and ‘never’ speak the language of the test at home is 76 points. In South Africa that difference is almost double, at 157, and in Botswana the difference is 46. Achievement scores of learners, across countries, who indicated the same level of language proficiency varied widely. Learners from South Africa who indicated that they ‘always’ spoke the language of the test achieved an average mathematics score of 347, in Botswana the comparable group achieved a score of 374, and in Singapore this group achieved a score of 613. In Singapore, 57 per cent of the learners indicated that they ‘sometimes’ or ‘never’ spoke the language of the test at home and their average mathematics score was 581. It might be worth probing further why Botswana, a neighbour of South Africa, showed a very small difference in achievement scores between those who ‘always’ and those who ‘never’ speak the language of the test at home. It is possible that the quality of the school inputs contributes to higher achievement.

The difference between the average science score for learners who ‘always’ and ‘never’ speak the language of the test at home is higher than the difference for the average mathematics score. The difference in the international average science score between learners who ‘always’ and ‘never’ speak the language of the test at home is 93 points. In South Africa that difference is almost double, at 194, and in Botswana the difference is 58.

South Africa has 11 official languages. The schools sampled for TIMSS reported that the official language of teaching and learning is either English or Afrikaans. Of the South African learners who answered that they ‘always’ speak the language of the test at home, 4.7 per cent were from ex-DET schools, 8.5 per cent from ex-HoR schools, 1.5 per cent from ex-HoD schools, and 5 per cent attended ex-HoA schools. Of the learners who attend ex-HoA schools, about 60 per cent ‘always’ speak the language of teaching and learning at home. Even with 40 per cent of learners not always speaking the language of the test at home, the ex-HoA schools achieve an average score in mathematics and science that is close to the international average.

The above analysis shows that there is an association between lower achievement and not speaking the language of the test at home. However, the effect of language proficiency and achievement scores is not straightforward. While it is acknowledged that proficiency in the language of the test is a contributor to the average achievement score, the comparison of South African scores with the scores of other countries (involving the categories of ‘language spoken’ and different school types in South Africa) suggests that there are factors other than language that contributing to low achievement scores – factors such as socio-economic variables, the nature of teaching and, importantly, the level of cognitive demand in classroom interactions in whatever language is used.

The above three factors – parents’ level of education, educational resources in the home, and the extent to which the language of the test is spoken at home – all indicate that even when these resources are available, the South African average TIMSS mathematics and science scores are lower than most other countries.

Attitudes towards learning mathematics and science

Creating a positive attitude in learners towards mathematics and science is an important goal of the education curriculum in many countries. Learners' motivation to learn can be affected by their self-confidence, whether they find the subject enjoyable, and the value they place on their subject. Learners were therefore asked questions relating to these aspects. TIMSS then created an index for each of these constructs. Interpreting responses to attitudinal questions in across-country contexts is difficult, as one would also need to consider the cultural contexts. Some learners respond with socially desirable answers; others with modest self-confidence, and it is thus difficult to ascertain a 'true' picture.

Self-confidence in learning mathematics and science

Four statements about learning mathematics were combined to form an index of learners' self-confidence in learning mathematics (SCM). Similarly, four statements were combined to form the index of learners' self-confidence in learning science (SCS). Table 9.6 shows the self-confidence and corresponding achievement scores for learners from several countries.

The SCM index is based on the responses to the following four statements:

- I usually do well in mathematics;
- Mathematics is more difficult for me than for many of my classmates;
- Mathematics is not one of my strengths; and
- I learn things quickly in mathematics.

The SCS index is based on the responses to the following four statements:

- I usually do well in science;
- Science is more difficult for me than for many of my classmates;
- Science is not one of my strengths; and
- I learn things quickly in science.

Table 9.6: Index of learners' self-confidence in mathematics (SCM) and self-confidence in science (SCS) and average mathematics and science scores

		High		Medium		Low	
		%	Score	%	Score	%	Score
South Africa	SCM	37%	300 (8.3)	48%	242 (3.9)	15%	255 (9.9)
	SCS	45%	282 (8.3)	46%	215 (5.7)	9%	207 (10.2)
Botswana	SCM	38%	390 (2.8)	45%	361 (2.5)	17%	352 (3.4)
	SCS	46%	391 (2.9)	44%	353 (3.4)	10%	337 (5.3)
Ghana	SCM	43%	306 (5.6)	44%	265 (4.8)	12%	265 (7.5)
	SCS	57%	294 (6.1)	36%	224 (6.2)	7%	173 (11.7)
Singapore	SCM	39%	639 (3.0)	34%	594 (3.9)	27%	571 (4.6)
	SCS	45%	601 (4.4)	37%	562 (4.9)	18%	553 (5.0)
Japan	SCM	17%	634 (3.1)	38%	580 (2.7)	45%	538 (2.3)
	SCS	20%	595 (2.7)	46%	551 (1.8)	34%	529 (2.3)
International average	SCM	40%	504 (0.6)	38%	453 (0.6)	22%	433 (0.7)
	SCS	48%	490 (0.8)	38%	445 (0.90	13%	430 (1.2)

Learners who agreed a lot or a little with all four statements were assigned to the high level of the index, while learners who disagreed a lot or a little were assigned to the low level. The medium level includes all other possible combinations of responses.

On average, internationally, 40 per cent of mathematics and 48 per cent of science learners had high self-confidence in learning their subject. In science, the percentages for self-confidence ranged from a high of 69 per cent in Tunisia to a low of 20 per cent in Japan. In mathematics, the percentages ranged from a high of 59 per cent in Israel to a low of 17 per cent in Japan.

Although there was a (slight) positive relationship within countries between self-confidence in science/mathematics to achievement scores (in South Africa the difference in the average achievement scores between those of high and low self-confidence is 45 for mathematics and 75 for science), the across-country level relationship is more complex. It is worth noting that the four countries with the lowest percentages of learners in the high self-confidence category – Chinese Taipei, Hong Kong SAR, Japan and Korea – all had high average mathematics and science achievement scores.

Enjoyment of mathematics and science

Learners were asked in the learner questionnaire to indicate (on a three-point scale) whether they liked mathematics or science. Table 9.7 shows how learners in South Africa and several other countries responded.

Table 9.7: Learners' response to the enjoyment of mathematics and science question

		Agree a lot % (SE)	Agree a little % (SE)	Disagree % (SE)
South Africa	Math	56% (1.2)	24% (1.0)	20% (1.0)
	Science	64% (1.0)	22% (0.8)	15% (0.6)
Botswana	Math	65% (1.0)	22% (0.8)	14% (0.7)
	Science	72% (1.0)	17% (0.8)	11% (0.5)
Ghana	Math	53% (1.2)	30% (0.8)	16% (0.9)
	Science	65% (1.2)	21% (0.9)	13% (0.8)
Singapore	Math	33% (0.7)	42% (0.7)	25% (0.8)
	Science	42% (0.9)	41% (0.7)	17% (0.6)
Japan	Math	9% (0.6)	30% (0.8)	61% (1.1)
	Science	19% (1.0)	40% (0.8)	41% (1.4)
International average	Math	29% (0.1)	36% (0.1)	31% (0.2)
	Science	44% (0.2)	33% (0.2)	23% (0.2)

Internationally, 29 per cent of the learners indicated that they enjoyed mathematics, while 44 per cent said that they enjoyed science. Interestingly, South Africa and Botswana are among the countries where the highest number of learners indicated they enjoyed mathematics and science and yet the performance is very low. Countries where the lowest number of learners indicated that they enjoyed mathematics are Japan (9 per cent), Republic of Korea (9 per cent), Slovenia (7 per cent) and Netherlands (6 per cent). With the exception of Slovenia, these countries are top-ten achievers.

Valuing mathematics and science

Learners' motivation to learn mathematics and science may be affected by whether they find the subject enjoyable; place value on the subject, and think it is important for success in school and for future career aspirations. To gain an understanding of the value that Grade 8 learners placed on mathematics and science, TIMSS created an index of learners valuing mathematics (SVM) and learners valuing science (SVS).

To create the SVM index, learners were asked to state their agreement with the following seven statements regarding mathematics:

- I would like to take more mathematics in school;
- I enjoy learning mathematics;
- I think learning mathematics would help me in my daily life;
- I need mathematics to learn other subjects;
- I need to do well in mathematics to get into the university of my choice;
- I would like a job that involved using mathematics; and
- I need to do well in mathematics to get the job that I want.

To create the SVS index, learners were asked to state their agreement with the following seven statements regarding science:

- I would like to take more science in school;
- I enjoy learning science;
- I think learning science would help me in my daily life;
- I need science to learn other subjects;
- I need to do well in science to get into the university of my choice;
- I would like a job that involved using science; and
- I need to do well in science to get the job that I want.

Learners who, on average, agreed a little or a lot with the seven statements were assigned to the high level of the index, while learners who, on average, disagreed a little or a lot with the statements were assigned to the low level. The medium level includes all other possible combinations of responses. Table 9.8 shows how learners in South Africa and several other countries responded.

Table 9.8: Index of learners valuing mathematics (SVM) and learners valuing science (SVS) and average mathematics and science scores

		High		Medium		Low	
		%	Score	%	Score	%	Score
South Africa	SVM	79%	271 (5.6)	17%	243 (9.1)	4%	241 (11.4)
	SVS	76%	242 (6.1)	19%	246 (11.6)	5%	270 (16.0)
Botswana	SVM	84%	378 (2.7)	14%	331 (2.8)	2%	–*
	SVS	85%	379 (2.7)	13%	315 (6.6)		
Ghana	SVM	82%	293 (4.8)	16%	227 (4.8)	1%	_*
	SVS	83%	279 (5.5)	16%	173 (8.4)		
Singapore	SVM	63%	616 (3.4)	32%	592 (4.0)	5%	558 (7.9)
	SVS	62%	599 (3.9)	33%	551 (4.6)	6%	505 (7.3)
Japan	SVM	17%	597 (3.1)	61%	574 (2.2)	22%	539 (3.3)
	SVS	17%	586 (3.3)	56%	555 (1.8)	27%	526 (2.8)
International average	SVM	55%	479 (0.6)	35%	458 (0.6)	10%	458 (1.0)
	SVS	57%	477 (0.8)	31%	450 (1.0)	12%	463 (1.6)

Note: A dash (–) denotes insufficient data to report achievement.

As shown in Table 9.8, internationally, on average, learners placed a high value on mathematics, with 55 per cent in this category, followed by 35 per cent in the medium category, and then 10 per cent in the low category. Countries who reported large percentages in the high valuing category included Morocco, Botswana, Ghana, Egypt, Jordan and South Africa. Among countries where few learners reported placing a high value on mathematics were Korea, Japan and the Netherlands.

Internationally, the difference in achievement scores between high-valuing learners and low-valuing learners for mathematics and science is less than 20. In South Africa, the difference between these two groups, for mathematics, is 30. The learners who reported low valuing of science achieved an average science score higher than those that indicated high and medium valuing.

Analysis of the learners' attitudes towards mathematics and science reveals that in many countries where positive attitudes were reported, the achievement scores were lower; while in many countries not reporting positive attitudes, the achievement scores were higher. In addition, the in-country difference between the groups was not high. Therefore, it is difficult to determine the association between attitudes to mathematics and science and the achievement scores in these subjects.

Summary

The parents' level of education, the existence of educational resources in the home, and the extent to which the language of the test is spoken at home were investigated, with the aim of determining what effect these factors have on mathematics and science achievement scores. The findings, as outlined in this chapter, indicate that within a country where learners have these resources, they perform better than those who do not have them. However, across-country comparisons show that even when these resources are in place, the South African average TIMSS mathematics and science scores are lower than the other countries. None of these factors on its own can explain performance – rather, it is the interaction of many factors, embedded within a context, which offers suggestions of why performance may be high or low.

In general, the attitude of South-African learners to mathematics and science is positive – they have high self-confidence; they enjoy and value the subjects. We must consider that these may be socially desirable responses, and that one would have to probe further to determine the 'real' attitudes of learners. Internationally, and within South Africa, there is no significant variation in achievement scores between learners who indicate positive attitudes towards mathematics and science and those who do not.

CHAPTER 10

The context of learning: teachers, classrooms and schools

Introduction

This chapter examines the context for TIMSS learners' learning; that is, teachers, classrooms and schools. The aim of this analysis is to describe those variables that are most likely to have an impact on, or be associated with, achievement.

This chapter draws on data collected for TIMSS 2003 by questionnaires completed by teachers and principals. The unit for sampling of learners within schools was an intact mathematics and science classroom. The mathematics teacher and the science teacher for that class were asked to complete a questionnaire for their respective subject. The mathematics and science teachers' responses to the questionnaires are not necessarily representative of all South African mathematics and science teachers, as they were simply the teachers of a representative sample of learners assessed as part of TIMSS 2003. This chapter should then be thought of as indicative of, rather than representative of, South-African teachers, classrooms and schools. When information from the teacher and school questionnaires was reported, the learner, however, remained the unit of analysis; that is, the data shown are the percentages of learners whose teachers or principals reported on various characteristics or instructional strategies.

The contextual framework

The major characteristics of the TIMSS-collected data reported on in this chapter are:

- Teachers and their preparation;
- Classroom characteristics, activities and resources; and
- The school context.

However, there is limited coverage in this chapter on each of these dimensions for two main reasons. Firstly, analysis of the teacher and learner questionnaires revealed different responses being given to the same exhibited phenomena. Secondly, responses to many questions seemed to be prompted by the need to say what would be considered socially desirable, and did not resonate with local understandings. This chapter will, therefore, describe the context of learning on several variables, but will not probe the degree of association between the variable and the achievement score. For an examination of the complete response set of South-African teachers, learners and principals, the international report should be consulted.

Science and mathematics teachers

The teacher is central in creating a supportive environment for learning science and mathematics. This section provides demographic information on the teaching force; teachers' academic preparation for teaching; professional development of teachers; and their readiness to teach the TIMSS curriculum topics. The South African response rate for most questions on the teacher questionnaire was between 70–85 per cent, a feature in about 20 per cent of other participating countries.

Mathematics teachers and their preparation for teaching

Gender, age and experience

In South Africa, about 40 per cent of mathematics learners were taught by females and 60 per cent by males. Internationally, 58 per cent of the learners were taught by female teachers. Countries where 40 per cent or less of mathematics learners were taught by females include: South Africa (40 per cent), Iran (39 per cent), Norway (36 per cent), the Netherlands (32 per cent), Tunisia (32 per cent), Japan (32 per cent), Botswana (27 per cent), Morocco (15 per cent), Egypt (14 per cent), and Ghana (11 per cent).

The majority of South African TIMSS mathematics teachers are aged between 30–39 years. The age profile of the teachers is as follows: 19 per cent of learners are taught by teachers aged between 20–29 years; 55 per cent are taught be teachers aged between 30–39 years; 21 per cent by teachers aged between 40–49 years, and 5 per cent by teachers older than 50. If there was a steady replenishment of the teaching force, one would expect about equal numbers of learners to be taught by teachers in the different age groups. This data suggests that in the last few years there have not been many new mathematics teachers joining the profession.

The average teaching experience of South African TIMSS mathematics teachers was 11 years, while the international average teaching experience was 16 years. Other countries where the average teaching experience of TIMSS mathematics teachers is less than 11 years were: the Philippines (11 years), Bahrain (11 years), Palestinian Authority (10 years), Saudi Arabia (10 years), Ghana (8 years), and Botswana (6 years).

Academic preparation

In 70 per cent of the TIMSS countries, the academic requirement for being a mathematics teacher is at least a university degree. That is not a requirement, as yet, in South Africa, although all new teachers need to register for a four-year degree qualification. Table 10.1 profiles the educational qualification levels of South African TIMSS mathematics teachers and teachers from other African countries.

Table 10.1: Highest educational level of mathematics teachers, by percentage of learners they teach

	Beyond first university degree	Finished university or equivalent	Finished post-secondary (not university)	Finished upper secondary	Did not finish upper secondary
South Africa	10	24	61	5	0
Botswana	0	8	89	3	0
Ghana	0	8	82	10	0
Egypt	1	99	0	0	0
Tunisia	61	32	2	5	0
Morocco	2	5	7	72	13
International average	17	59	20	4	0

Internationally, about three-quarters of learners are taught by teachers with a university qualification. Despite, on average, a relatively well-educated teaching force, the situation varied across countries. For example, at least half the learners were taught by teachers who had a qualification higher than an initial degree in Armenia, Australia, Bulgaria, the Russian Federation, Tunisia, and the United States. By way of contrast, 72 per cent of learners in Morocco were taught by teachers who had only completed secondary schooling.

In South Africa, 95 per cent of the TIMSS learners are taught by mathematics teachers who indicated they had completed a post-secondary qualification – of these, one-third are taught by teachers with at least an initial university qualification. About two-thirds of South-African learners were taught by teachers who indicated that they had studied for mathematics in their pre-service training courses. From this information it is possible to say that at least two-thirds of the Grade 8 mathematics learners are taught by a teaching force considered as qualified with respect to the content knowledge. Relatively speaking, however, the South African mathematics teaching force appears in the group with the least qualifications.

Professional development

In addition to the formal training for teaching mathematics, teachers have to update their knowledge continually. Teachers responding to the TIMSS questionnaire were asked about their participation in different types of professional development activities in the past two years. Table 10.2 indicates the involvement in professional development activities by teachers from South Africa and other African countries.

Table 10.2: Percentage of learners taught by teachers who had participated in professional mathematics development in the past two years

	Math content	Math pedagogy/ instruction	Math curriculum	Integrating info tech to math	Improving critical thinking	Mathematics assessment
South Africa	61	43	59	34	58	77
Botswana	39	24	18	17	50	40
Ghana	50	40	41	20	52	57
Egypt	28	49	28	48	80	60
Tunisia	26	42	22	16	46	46
International average	57	57	52	43	47	49

Internationally, between 43–57 per cent of learners were taught by teachers who indicated that they had participated in professional development activities in the past two years. The highest percentages were in activities related to mathematics content and pedagogy/instruction. South African teachers attended a higher number of professional development activities than the international average for activities related to mathematics content, mathematics curriculum, improving critical thinking, and mathematics assessment. South African teachers participated in a higher number of professional development activities than almost all the other African countries surveyed.

South Africa's high attendance at professional development activities in the past two years may be because the new OBE curriculum was introduced to Grade 8 classes for the first time in 2001. Teachers were invited to a number of professional development activities (offered by the national and provincial departments of education, universities and non-governmental organisations) relating to the new curriculum and its assessment. However, it is surprising that there was a relatively low percentage reporting on professional development activities relating to mathematics pedagogy or instruction, given that C2005 introduced a different way of organising classroom activities.

TIMSS only asked teachers about their attendance at professional development activities and not about the nature and quality of such activities. Given that many teachers reported that they had attended professional activities, and that these activities could provide leverage for improving the educational system, it is important to follow up on the nature and quality of these activities.

Readiness to teach

TIMSS 2003 asked teachers how ready they felt to teach the mathematics topics included in the TIMSS 2003 mathematics framework. Across the five content areas (number, algebra, measurement, geometry, and data), the Grade 8 teachers were asked about readiness in 18 sub-areas. Internationally, most teachers (that is, over 85 per cent) reported that they felt ready to teach most topics.

In South Africa, there was a similar pattern regarding the issue of readiness to teach. In 14 of the 18 topics queried, over 85 per cent of teachers indicated their readiness to teach that topic. Topics where less than 85 per cent of teachers indicated a readiness to teach were: measurements of irregular or compound areas (79 per cent); translation, reflection, rotation and enlargement in geometry (81 per cent); sources of error in collecting and organising data (83 per cent); and simple probability (83 per cent).

Science teachers and their preparation for teaching

Gender, age and experience

About equal numbers of South African TIMSS learners were taught by male and female science teachers. Internationally, 60 per cent of the learners were taught by female teachers and 40 per cent by male teachers. Countries where 40 per cent or less of the learners were taught by female teachers include: Norway (40 per cent), Iran (39 per cent), Botswana (39 per cent), Morocco (34 per cent), Tunisia (32 per cent), the Netherlands (27 per cent), Japan (20 per cent), Egypt (14 per cent), and Ghana (11 per cent).

The majority of South African TIMSS science teachers are aged between 30–39 years. The age profile of South African TIMSS science teachers is as follows: 24 per cent of learners are taught by teachers aged between 20–29; 51 per cent are taught by teachers aged between 30–39; 20 per cent by teachers aged between 40–49; and 4 per cent are taught by teachers above the age of 50. As for mathematics, this data suggests that in the last few years there have not been many new science teachers joining the profession.

The average teaching experience of South African TIMSS science teachers was 10 years. The international average number of years of teaching experience of the TIMSS science teacher was 15 years. Countries where the average experience of TIMSS science teachers is less than 10 years were: Bahrain (9 years), Cyprus (9 years), Palestinian Authority (9 years), Saudi Arabia, Ghana (8 years), and Botswana (6 years).

Academic preparation

In 70 per cent of the TIMSS countries, the academic requirement for being a mathematics teacher is at least a university degree. That is not a requirement, as yet, in South Africa, although all new teachers need to register for a four-year degree qualification. Table 10.3 profiles the educational qualification levels of South African TIMSS science teachers and teachers from other African countries.

Table 10.3: Highest educational level of science teachers, by percentage of learners they teach

	Beyond first university degree	Finished university or equivalent	Finished post-secondary (not university)	Finished upper secondary	Did not finish upper secondary
South Africa	7	21	69	2	0
Botswana	4	34	61	1	0
Ghana	0	9	79	12	0
Egypt	8	92	0	0	0
Tunisia	81	17	1	0	0
Morocco	2	32	16	44	5
International average	22	57	18	3	0

Internationally, about 80 per cent of learners are taught by teachers with a university qualification. Despite, on average, a relatively well-educated teaching force, the situation varied across countries. For example, at least half the learners were taught by teachers who had a qualification higher than the initial degree in Armenia, Australia, Bulgaria, Lithuania, New Zealand, the Russian Federation, the United States, and the Basque region of Spain. By way of contrast, 44 per cent of learners in Morocco, and 25 per cent in Malaysia, were taught by teachers who had only completed secondary schooling.

In South Africa, 98 per cent of the TIMSS learners were taught by science teachers who indicated they had completed a post-secondary qualification – of these, 28 per cent of learners are taught by university-qualified teachers. About three-quarters of South-African learners were taught by teachers who reported that their major area of study during their pre-service training included biology, physics, chemistry, or Earth sciences. From this information it is possible to say that at least three-quarters of the Grade 8 science learners are taught by a teaching force considered qualified with respect to the content knowledge. Relatively speaking, with the exception of Ghana, the South African science teaching force seems to have the fewest number of teachers with a four-year qualification or above.

Professional development

In addition to the formal training for science teaching, teachers have to update their knowledge continually. Teachers responding to the TIMSS questionnaire were asked about their participation in different types of professional development activities in the past two years. Table 10.4 indicates the involvement in professional development activities by teachers from South Africa and other African countries.

Table 10.4: Percentage of learners taught by teachers who had participated in professional science development in the past two years

	Science content	Science pedagogy/ instruction	Science curriculum	Integrating info tech into science	Improving critical thinking	Science assessment
South Africa	64	40	55	39	52	67
Botswana	27	22	10	18	32	33
Ghana	50	39	45	30	44	53
Egypt	41	56	27	49	66	66
Tunisia	29	56	42	28	48	54
International average	58	56	52	45	45	47

Internationally, between 45–58 per cent of learners were taught by teachers who indicated that they had participated in professional development activities in the past two years. The highest percentages were in activities related to science content and pedagogy/ instruction. South African teachers attended a higher number of professional development activities than the international average for activities related to science content, science curriculum, improving critical thinking, and science assessment. South African teachers participated in a higher number of professional development activities than almost all the other African countries surveyed.

South Africa's high attendance at professional development activities in the past two years may be because the new OBE curriculum was introduced to Grade 8 classes for the first time in 2001. Teachers were invited to a number of professional development activities (offered by the national and provincial departments of education, universities and non-governmental organisations) relating to the new curriculum and its assessment. However, it is surprising that there was a relatively low percentage reporting on professional development activities relating to science pedagogy or instruction, given that C2005 introduced a different way of organising classroom activities.

TIMSS only asked teachers about their attendance at professional development activities and not about the nature and quality of such activities. Given that many teachers reported that they had attended professional activities, and that these activities could provide leverage for improving the educational system, it is important to follow up on the nature and quality of these activities.

Readiness to teach

TIMSS 2003 asked teachers how ready they felt to teach the science topics included in the TIMSS 2003 science framework. Across the five content areas (life science, chemistry, physics, earth science, and environmental science) the Grade 8 teachers were asked about their readiness to teach science in these areas, which were then divided into 21 topics. Internationally, over 90 per cent most teachers reported that they felt ready to teach most topics, except the three earth science topics and two of the three environmental science topics, where 85 per cent reported readiness.

In South Africa, there was a similar pattern regarding the issue of readiness to teach. In 13 of the 21 topics queried, over 85 per cent of teachers indicated their readiness to teach that topic. Topics where less than 85 per cent of teachers indicated a readiness to teach were: chemical change (77 per cent); physical states and changes in matter (82 per cent); and basic properties/behaviours of light and sound (77 per cent). For the environmental science topics, less than 85 per cent of teachers reported readiness in two areas: trends in human population and its effects on the environment (81 per cent), and changes in environments (76 per cent). Lower numbers of teachers reported readiness to teach the topics of earth science, with about two-thirds (approximately 66 per cent) indicating readiness in the topics of earth's structure and physical features; earth's processes, cycles and history; and earth in the solar system and the universe. This is not unexpected, as those topics were previously covered in a different part of the school curriculum (namely Geography) and would have been taught by a different teacher.

Classroom characteristics, activities and resources

Although the school provides the general context for learning, it is in the classroom setting and through the teacher's guidance that most instruction and learning takes place. In this section we will report on class size, time allocated for the teaching of mathematics and science, learner activities, textbooks for mathematics and science teaching, and test-item formats in mathematics and science classes.

Class size

Class size could affect the interactions and activities in a classroom. Table 10.5 provides information on this aspect for the TIMSS African countries.

Table 10.5: Mathematics and science class size, by percentage of learners in different class sizes and average mathematics scores

	Class size	1–24 learners	25–32 learners	33–41 learners	>41 learners
South Africa	45	4%	14%	30%	52%
		309 (35.8)	290 (23.8)	265 (11.7)	249 (8.7)
Botswana	37	1%	14%	60%	25%
		–	392 (9.1)	360 (3.7)	362 (4.1)
Ghana	37	16%	18%	29%	37%
		232 (7.4)	249 (8.9)	292 (9.0)	289 (9.1)
Egypt	38	3%	9%	61%	27%
		422 (13.8)	428 (11.3)	403 (4.3)	407 (7.5)
Tunisia	34	1%	26%	71%	2%
		–	404 (3.6)	412 (3.2)	–
International average	30	29%	35%	24%	13%
		461 (1.9)	473 (1.4)	470 (2.1)	448 (1.7)

Note: A dash (–) indicates that there was insufficient data to report.

Internationally, the average number of learners per TIMSS mathematics and science class was 30. There is variation in the average class size of different TIMSS countries – from the Philippines, with an average of 54 learners, to Belgium (Flemish), with an average of 20 learners. In South Africa the average class size was 45 – the second highest of all TIMSS participants.

Within a country there is a slight association, as expected, between mathematics achievement scores and class sizes – the scores were higher where class size was smaller. However, across countries, same-sized classes attained different achievement scores. For example, South African learners in classes where there were less than 24 learners attained a mathematics score of 309, whereas in Egypt a same-sized group attained a score of 422. Over half (52 per cent) of the South African learners were in classes with greater than 41 members and they attained a mathematics score of 249. In Botswana, a quarter of the learners were in classes with greater than 41 members and they attained a mathematics score of 362.

Other countries where over 40 per cent of the learners are in class sizes greater than 41 were: Philippines (91 per cent), Palestinian National Authority (50 per cent), Indonesia (48 per cent), and Hong Kong SAR (43 per cent). With the exception of Hong Kong, it would seem that class size affects performance in mathematics and science, as all the other countries achieved scores at the lower end of the spectrum..

Time allocated for mathematics and science

According to the guidelines in the curriculum questionnaire, the amount of time allocated for the teaching of mathematics and science at the Grade 8 level is, respectively, 13 per cent and 11 per cent of instructional time.

Learner activities in mathematics and science classrooms

Mathematics

TIMSS mathematics teachers were asked to report on the percentage of learners who spent more than half the lessons on the following mathematics content-related activities in the classroom. The South African mathematics teachers' responses were as follows:

- Practise adding, subtracting, multiplying and dividing without using a calculator (63 per cent);
- Work on fractions and decimals (26 per cent);
- Interpret data in tables, charts or graphs (26 per cent); and
- Write equations and functions to represent relationships (25 per cent).

Internationally, teachers reported the largest percentage of learners practising operations (62 per cent) and working on fractions and decimals (43 per cent). Less emphasis was placed on writing equations (30 per cent) and data interpretation (17 per cent). Compared to the international average, South African learners spend less time on fractions and decimals and more time on data interpretation.

The goal of improving learners' capacity for mathematics problem solving is important in all educational systems. TIMSS asked Grade 8 teachers how often learners were asked to perform the following activities – relate what is being learnt in mathematics to their daily lives; explain their answers, and decide procedures for solving complex problems.

The South African teachers' reported their learners allocating time to these activities in the following manner:

- Relating what is being learnt in mathematics to their daily lives (59 per cent);
- Explaining their answers (67 per cent); and
- Deciding procedures for solving complex problems (36 per cent).

Internationally, teachers reported a greater emphasis placed on asking learners to explain answers (about three-quarters of learners, in at least half the lessons) than asking learners to relate mathematics to their daily lives and to decide on procedures for solving complex problems (about half the learners doing so). There was a low emphasis in South African classrooms on asking learners to decide procedures for solving complex problems.

The emphasis on the content-related and problem-solving activities reported by South African mathematics teachers was in line with international trends.

Science

TIMSS science teachers were asked to indicate how instructional time in science was allocated across the five major content areas assessed in TIMSS 2003.

South African teachers reported the following allocation of time to each of the content areas:

- Life science (26 per cent);
- Chemistry (21 per cent);
- Physics (21 per cent);
- Earth sciences (13 per cent); and
- Environmental sciences (15 per cent).

Internationally, on average, the most time was devoted to life science (27 per cent). This was followed by physics (24 per cent), chemistry (21 per cent), earth science (13 per cent), and environmental science (9 per cent).

In many countries, the science curriculum places emphasis on engaging learners in scientific inquiry. TIMSS science teachers were asked to report on the percentage of learners who spent more than half the lessons on the following activities relating to scientific inquiry. The South African science teachers' responses were as follows:

- Watch the teacher demonstrate an experiment or investigation (24 per cent);
- Design or plan experiments or investigations (40 per cent);
- Conduct experiments or investigations (34 per cent);
- Work together in small groups on experiments or investigations (55 per cent);
- Write explanations of what was observed and why it happened (55 per cent); and
- Relate what learners are learning in science to daily lives (77 per cent).

Internationally, teachers of 38 percent of learners reported asking their learners to watch them demonstrate an experiment or investigation in at least half the lessons. The corresponding percentages of learners for designing or planning experiments or investigations was 31 per cent; for conducting experiments or investigations the figure was 54 per cent; for working together in small groups on experiments or investigations it was 57 per cent; for writing explanations of what was observed and why it happened accounted for 61 per cent, and for relating what learners are learning in science to daily lives the figure was 77 per cent.

The South African time allocation for each of the content areas (except environmental science) was similar to the international average. The international average and the prevalence of the scientific inquiry activities in South Africa was similar in all categories, except for watching a demonstration of an experiment or conducting an experiment. It would seem, in South Africa, that less than a third of the learners watched a demonstration or conducted an experiment.

Textbooks in mathematics and science classrooms

The textbook is an important resource for the teaching and learning of mathematics and science. Internationally, about two-thirds of mathematics teachers and just over half the science teachers reported using the textbook as the primary basis for their lessons. For the remaining group (approximately one-third of the mathematics and science teachers) the textbook was reported as a supplementary resource.

In South Africa, one-third of mathematics and science teachers reported that they used textbooks as the primary basis for lessons; the others used it as a supplementary resource. About one-third of mathematics and science teachers reported that shortage of textbooks for learners was one of the factors that limited the teaching in the classroom.

South African teachers were encouraged by C2005 to use a range of resources to develop a set of materials and activities for their learners. This could account for the lower reporting of the use of the textbook as a primary basis for lessons. Countries where over 80 per cent of the learners were taught by teachers reporting textbook use as the primary basis for lessons were: Chinese Taipei, Estonia, Hong Kong, Jordan, Korea, Lithuania, Moldova, Netherlands, Norway, Palestinian National Authority, Russian Federation, Scotland, and Sweden. In South Africa, we might have to re-examine the role the textbook performs as a primary basis for lessons.

Test item format

Mathematics and science teachers were asked to report on the extent to which they used multiple-choice and constructed-response questions in their classroom tests and examinations. Table 10.6 provides information on the percentage of learners who were given the two item formats in classroom tests and examinations, as reported by teachers.

Table 10.6: Item formats used by mathematics and science teachers in classrooms as reported by percentage of learners

	Only or mostly constructed response	About half constructed response and half MCQs	Only or mostly MCQs
Mathematics			
South Africa	45	44	11
International	56	32	12
Science			
South Africa	16	72	11
International	28	60	13

For South Africa, at least 55 per cent of the learners were exposed to mathematics MCQs, and at least 90 per cent to mathematics constructed-response questions. In science, at least 80 per cent of the learners were exposed to MCQs and at least 90 per cent to constructed-response questions. The South African patterns are similar to international patterns, and the type of questions asked in the TIMSS instrument would be familiar to most learners.

School contexts

Educational inputs largely take place in schools and these institutions are prime sites for the development of learner potential and performance. In poorer communities, the importance of the schools' role is particularly crucial. In these communities, and in developing countries, the schools very often substitute for a lack of cultural capital and home support; valuable resources that are typically present in more affluent communities and developed countries.

The school provides the context for teaching and learning the curriculum, including, for the purposes of this report, mathematics and science. In this section, information on the demographic characteristics of schools, school resources for mathematics and science teaching, perceptions of school climate, and school attendance problems will be provided. The data appearing in this section was collected from school principals and the mathematics and science teachers.

Schools demographic characteristics

The economic resources of the home and community have an influence on learner achievement. Principals were asked to indicate the percentage of learners in their schools who came from economically disadvantaged homes. Table 10.7 details the principals' responses.

Table 10.7: Principals' reports on the percentage of learners in their schools coming from economically disadvantaged homes, and their average mathematics score

	GNI per capita in US dollars	0–10% economically disadvantaged learners	11–25% economically disadvantaged learners	26–50% economically disadvantaged learners	> 50% economically disadvantaged learners
South Africa	2 500	3% 479 (44.9)	2% –	9% 334 (25.7)	85% 237 (3.4)
Botswana	3 010	15% 385 (11.0)	22% 375 (6.2)	25% 363 (3.2)	38% 354 (3.2)
Ghana	270	4% 295 (24.1)	8% 308 (14.9)	18% 286 (9.0)	71% 264 (5.9)
Egypt	1 470	11% 448 (11.8)	24% 410 (8.2)	23% 393 (6.3)	42% 392 (5.5)
International Average		22% 496 (2.1)	26% 476 (1.3)	21% 460 (1.5)	31% 439 (1.3)

Note: A dash (–) indicates that there was insufficient data to report.

Principals in each country used a definition of economic disadvantage that was relevant to their country. However, this means it is difficult to compare the percentage of learners in the different categories across countries.

In some countries; for example, Chile, Ghana, Indonesia, Lebanon, Malaysia, Morocco, the Palestinian National Authority, the Philippines, South Africa, and Tunisia, principals reported that more than half (52 to 85 per cent) the learners attended schools where the majority of learners came from disadvantaged homes.

Internationally, mathematics achievement scores for learners in schools with few (0–10 per cent) learners from economically disadvantaged homes were 57 scale points higher than for learners in schools possessing a higher percentage (more than 50 percent) of economically disadvantaged learners – 496 points versus 439 points. In South Africa, the average mathematics score for learners in schools with few (0–10 per cent) economically disadvantaged learners was 479, and 237 in schools where more than 50 per cent of the learners come from economically disadvantaged homes – a difference of 242 points. The figures reveal that in South Africa there is a significant impact on achievement scores when a high percentage of learners from economically disadvantaged homes are part of the school population.

School resources to support mathematics and science teaching

Some school resources are specific to mathematics and science, but many are general resources for improving learning opportunities across the curriculum. All resources work together to support mathematics and science teaching and learning.

TIMSS created an index of school resources for mathematics and science. The index for school resources for mathematics was based on the average response to five questions about shortages that affect the general capacity to provide instruction (instructional materials, budget for supplies, school buildings and grounds, heating/cooling and lighting systems, instructional space) and five questions about shortages that specifically affect mathematics teaching (computers for mathematics, computer software for mathematics instruction, calculators for mathematics instruction, library materials relevant to mathematics instruction, and audio-visual resources for mathematics instruction).

The index for availability of school resources for science was constructed in a similar way. The five questions about the general capacity to provide instruction were the same as those described for mathematics and the six questions about shortages that specifically affect science teaching were: science laboratory equipment and materials, computers for science instruction, computer software for science instruction, calculators for science instruction, library materials relevant to science instruction, and audio-visual resources for science instruction.

Learners were placed in the high category if principals reported that shortages, both general and those affecting mathematics in particular, had no or little effect on instructional capacity. The medium level indicates that one type of shortage affected instruction 'some' or 'a lot' and the low level indicates that both types of shortages affected instruction 'some' or 'a lot'. Table 10.8 indicates the percentage of learners in the high, medium and low categories of availability of resources for mathematics and science.

Table 10.8: Index of availability of school resources for mathematics and science, by percentage of learners

	High	Medium	Low
Mathematics			
Availability of resources in South Africa	8	53	39
Availability of resources internationally	26	64	11
Science			
Availability of resources in South Africa	9	52	39
Availability of resources internationally	22	63	12

Internationally, the countries which reported the highest availability of resources for mathematics and science teaching and learning were: Singapore, Hong Kong, the Netherlands, Belgium, Japan, and Australia. Countries which reported the lowest availability of resources for mathematics and science were: Moldova, Bulgaria, the Russian Federation, Serbia, and Botswana. The countries which indicated a high availability of resources attained high achievement scores in mathematics and science. For countries that reported low availability of resources their achievement scores were varied – from high to average to low.

In South African schools, there was a small percentage of schools with a 'high' availability of resources for mathematics and science. About 40 per cent of learners were in schools where principals indicated that the resources for mathematics and science teaching was 'low'. Comparing the South African and the international average suggests that the availability of resources for the teaching and learning of mathematics and science could affect learning outcomes.

Perceptions of school climate

The school environment establishes the climate for learning. TIMSS created two indices to measure the extent to which schools offer a positive school climate – one measured the views of principals and the other the views of teachers. The index was created on the principals and teachers characterisations of the following:

- Teachers' job satisfaction;
- Teachers' understanding of the schools' curricular goals;
- Teachers' degree of success in implementing the schools' curricula;
- Teachers' expectations for learners' achievement;
- Parental support for learners' achievement;
- Parental involvement in schools' activities;
- Learners' regard for school property; and
- Learners' desire to do well in school.

Learners in the high category attended schools where the principals (or teachers) averaged high, or very high, reports for each aspect of school climate. Learners whose principals (or teachers) characterised the school climate as medium were placed in the medium category and principals (or teachers) characterising the school climate as low or very low were placed in the low category. The index of principals' perception of school climate (PPSC) and teachers' perception of school climate (TPSC) is presented in Table 10.9.

Table 10.9: Index of principals' perception of school climate (PPSC) and teachers' perception of school climate (TPSC), by percentage of learners

		High	Medium	Low
South Africa	PPSC	7	45	48
	TPSC	10	46	44
Botswana	PPSC	1	31	68
	TPSC	3	29	68
Ghana	PPSC	13	68	18
	TPSC	17	54	30
International average	PPSC	15	67	18
	TPSC	10	60	30

Internationally, countries where a high number of both the principals and teachers (>40 per cent of learners in these schools) rated the perception of school climate as low were South Africa, Tunisia and Botswana. Countries where a high number of both principals and teachers rated the perception of school climate as high were the United States, Chinese Taipei, Philippines and Israel.

In South Africa, the principals and teachers rated the school climate in a similar way. Approximately half the learners are in schools where the principals' and mathematics and science teachers' perception of school climate is 'low'. Most countries which rated the school climate as high achieved higher achievement scores in mathematics and science. To improve mathematics and science learning in South African schools, interventions facilitating a more conducive teaching and learning environment would seem advisable. By doing this, current negative perceptions of school climate can be replaced by more positive ones, which can only benefit the teaching and learning experience of all concerned.

School attendance problems

School attendance can affect achievement and attitudes regarding mathematics and science. TIMSS constructed an index of good school and class attendance (GSCA), based on schools' responses to three questions about the seriousness of:

- Learners' absenteeism;
- Arriving late at school; and
- Skipping school.

The high index level indicates that a school reported that all three behaviours are not a problem. The low index level indicates that two or more behaviours are a serious problem, or two are a minor problem and one a serious problem. The medium category includes all other possible combinations of the responses. Table 10.10 presents the results of the index.

Table 10.10: Index of good school and class attendance (GSCA), by percentage of learners

	High GSCA	Medium GSCA	Low GSCA
South Africa	6	50	44
Botswana	5	62	33
Ghana	8	69	23
International	23	58	19

Internationally, countries where a high percentage of learners (> than 40 per cent) attended schools classified on the low-level index for GSCA were Lithuania, South Africa and Japan. Countries which achieved the highest GSCA were: Lebanon, Italy, Korea, Chinese Taipei and Belgium – that is, these schools have good school and class attendance.

The data suggests that in South Africa, school and class attendance is a problem – 44 per cent of learners attend schools where the GSCA is classified as low. Efforts to ensure better attendance by learners in South African schools would be energy well spent, as the clear correlation between good attendance and good academic results can only benefit the teaching and learning of mathematics and science in the country.

Summary

Teachers

In South Africa, about 40 per cent of mathematics learners and 50 per cent of science learners were taught by female teachers. The majority of mathematics and science teachers are aged between 30–39, while the average teaching experience of mathematics and science teachers is 11 and 10 years respectively. The international average teaching experience for mathematics and science teachers is 16 and 15 years respectively.

Internationally, about three-quarters of learners are taught by mathematics and science teachers with a university qualification. In South Africa, over 95 per cent of the TIMSS learners are taught by mathematics and teachers who indicated they had completed a post-secondary qualification. Over two-thirds of mathematics and science learners were taught by teachers who indicated that they had studied either mathematics or science in their pre-service training courses. Therefore, the South African mathematics and science teachers could be classified as qualified and knowledgeable in their subject areas. However, in relation to the TIMSS cadre of teachers, the South African mathematics and science teachers appear among the group having the lowest qualifications.

Internationally, about half the learners were taught by teachers who indicated that they had participated in professional development activities in the past two years. The type of professional development activities that most teachers participated in related to mathematics content, pedagogy or instruction. South African teachers attended a higher number of professional development activities than the international average for activities related to mathematics or science content, mathematics or science curriculum, improving critical thinking, and mathematics or science assessment. However, it is surprising that there was a relatively low percentage reporting on professional development activities relating to mathematics or science pedagogy or instruction, given that C2005 introduced a different way of organising classroom activities.

Classrooms

Internationally, the average number of learners per TIMSS mathematics and science class was 30. In South Africa, the average class size is 45 – the second highest of all TIMSS participants. The South African average class size is large and there are 52 per cent of learners in classes having a class size greater than 41. Within a country there is a slight association, as expected, between achievement score and class size – the score is higher where the class size is smaller. Across countries, learners in similar class sizes achieve different achievement scores.

The emphasis on mathematics and science content-related activities in South Africa and internationally is similar. Also, the emphasis on problem-solving activities in mathematics and scientific investigations in science for South Africa mirrors the international trend.

Internationally, about two-thirds of mathematics teachers, and just over half the science teachers, reported using the textbook as the primary basis for their lessons, the remaining third reported it as a supplementary resource. In South Africa, one-third of mathematics and science teachers reported that they used textbooks as the primary basis for lessons; the others used it as a supplementary resource.

Schools

In South Africa, principals indicated that 3 per cent of learners attended schools with 0–10 per cent economically disadvantaged learners; 2 per cent attended schools with 11–25 per cent economically disadvantaged learners; 9 per cent attended schools with 26–50 per cent economically disadvantaged learners; and 85 per cent attended schools with more than 50 per cent economically disadvantaged learners present. Internationally, the mathematics achievement score for learners in schools with few (0–10 per cent) learners from economically disadvantaged homes was 57 scale points higher than for learners in schools with a higher percentage (more than 50 per cent) of economically disadvantaged learners – 496 points as opposed to 439 points. In South Africa, the average mathematics score for learners in schools with few (0–10 per cent) economically disadvantaged learners is 479, and it is 237 in schools where more than 50 per cent of the learners come from economically disadvantaged homes – a difference of 242 points. In South Africa, there is a high impact on achievement scores of having a high percentage of learners from economically disadvantaged homes.

The response to questions about school climate indicated that about 40 per cent of learners attended schools which had a low resource base for mathematics and science teaching and learning. Furthermore, about half the learners attended schools rated by teachers and principals as having a low school climate, and 44 per cent of learners attended schools which teachers and principals rated as having low school and class attendance. The school climate and environment for most learners do not seem to be conducive to high quality teaching and learning of mathematics and science.

CHAPTER 11

Key findings and implications

Introduction

TIMSS 2003 looked at the mathematics and science achievements of 50 participating countries. Data for southern-hemisphere countries, including South Africa, was collected in the latter part of 2002; for the northern-hemisphere countries participating, data was collected in the first half of 2003.

This report describes the achievements (at an international and national level) in mathematics and science of South African learners in TIMSS 2003. Around 9 000 South African Grade 8 learners participated in TIMSS 2003. In addition to mathematics and science achievement data, information relating to learners, teachers, classrooms and schools was also collected. This allowed a contextual analysis of achievement results to be made and relevant improvement strategies to be suggested. This chapter provides the key findings from the TIMSS research, as well as implications for policy, practice and research.

Key findings

1. Benefits and limitations of comparative studies

- The principal benefit of cross-national studies is that a country's academic performance, in this instance, South Africa's, can be benchmarked against the performance of other countries displaying similar characteristics. This comparative analysis is useful in generating or eliminating hypotheses seeking to explain and understand a country's performance.
- A limitation of TIMSS for South Africa is that the achievement scores of learners are low and the distribution of scores is skewed toward the left (the 'floor effect'). This skewed distribution makes it much more difficult to generate and develop models explaining performance using the available data.

2. South African TIMSS achievements in an international context

- The top performing TIMSS countries for mathematics and science achievements were Singapore, Republic of Korea, Hong Kong (SAR), Chinese Taipei, Japan and Estonia. The lowest performing countries were Lebanon, the Philippines, Botswana, Saudi Arabia, Ghana and South Africa.
- South Africa had the lowest performance scores in mathematics and science compared to the other TIMSS participants.
- The international average scale score for mathematics was 467 (SE = 0.5), and for science, 474 (SE = 0.6). The South African scores were 264 (SE = 5.5) and 244 (SE = 6.7) respectively.
- South Africa had the largest variation in scores, ranging from a preponderance of very low scores to a few very high scores, so skewing the score distribution to the left (the abovementioned 'floor effect').
- South African performance in mathematics and science at the international benchmarks is disappointing, with only around 10 per cent in mathematics and 13 per cent in science achieving scores higher than 400 points. This means that

South Africa, in conjunction with Ghana, had the highest percentages of learners scoring less than 400 points (that is, below the LIB).

3. Gender analysis

- In most countries, including South Africa, there were equitable participation rates in mathematics and science classes between girls and boys. This was also the pattern in all the South African provinces, except in Eastern Cape and Gauteng where about 8 per cent more girls than boys participated.
- The international average mathematics scale score for girls and boys was not significantly different, but the average science scale score for boys was statistically higher than for girls by six points.
- In South Africa, the difference in the national average mathematics and science scale scores for girls and boys was not statistically significant.
- Although there are differences in the provincial average mathematics and science scale scores for boys and girls, this difference was not statistically significant.
- In TIMSS 2003, the difference between the achievement scores of boys and girls in schools categorised by ex-racial departments was not statistically significant.
- In TIMSS 1999, the mathematics and science scores of girls in the ex-African schools were statistically lower than the boys. While it is a positive sign that there is no difference in the TIMSS 2003 scores for boys and girls, the remaining concern is that both groups still present low scores.

4. Participation patterns at Grade 8 level

- The average age of South African learners in TIMSS 2003 (administered in November 2002) was 15.1 years. This is 0.4 years lower than the average age of 15.5 years in TIMSS 1999 (administered in 1998).
- This drop in the average age, from 1998 to 2002, implies that there is either less repetition in the system or fewer learners leave the system and then re-enter.

5. Performance patterns at Grade 8 level

By province

- The average achievement scores in mathematics and science of the provinces showed great variation.
- The top performing provinces were Western Cape and Northern Cape and the lowest performing provinces were Eastern Cape and Limpopo.
- The top performing provinces had scores which were almost double those of the lowest performing provinces.
- The socio-economic conditions in the provinces differ; the top performers having a higher GDP than that of the poorer performing provinces.

By schools categorised by ex-racial department

- There were differences in the average mathematics and science achievement scores of learners in schools categorised by ex-racial department.
- Learners who were in ex-HoA school (previously only for white learners) achieved an average mathematics and science score that was close to the international average.
- The average score of learners in African schools was almost half that of learners in ex-HoA schools.
- There has been a migration of better performing and financially resourced African learners to ex-HoA schools (where more resources are available). This means

that African schools have to contend with both the negative repercussions of apartheid's separatist education policies, *and* the migration of better performing learners – leaving these schools in the difficult position of having to produce good results under poor conditions.

- These achievement scores of the different school types (categorised by ex-department) indicate that attendance of learners at different school types is an important determinant in influencing learner achievement outcomes.

By language of the test

- Learners answered the test in either Afrikaans or English.
- Those learners who took the test in Afrikaans achieved an average mathematics score of 370 and an average science score of 376. Learners who took the test in English achieved an average mathematics score of 253 and an average science score of 231.
- Learners taking the test in Afrikaans were first-language users and their score would place this group just above the average score for Botswana on the international table.
- Most learners taking the test in English would be attending African schools and English would not be their first language.
- While the language of the test and learner proficiency in that language contributed to the achievement scores attained, it is difficult to determine the extent of this contribution as there are other inequalities among the different school types also influencing performance.

By what learners know and can do

- South African learners performed poorly on almost all test items.
- In most MCQs, less than 30 per cent of the learners achieved the correct answer.
- The average per cent correct on all mathematics and science items was just below 20 per cent.
- In mathematics, South African learners performed relatively well in the domains of measurement and data and performed most poorly in geometry.
- In science, they performed better in the chemistry domain, while performance was weakest in physics and earth science.

6. Trends in mathematics and science achievement

- The national achievement scores for mathematics and science were not significantly different, statistically, between TIMSS 1999 and TIMSS 2003. During this period there had been curriculum restructuring in the country.
- There were no statistically significant changes in the provincial mathematics scores in these two periods.
- In science, the increase in scores from TIMSS 1999 to TIMSS 2003 for Northern Cape and Limpopo is statistically significant.
- The mathematics score for African schools decreased 'significantly' from TIMSS 1999 to TIMSS 2003.

7. Performance at Grade 9 level

- The Grade 9 performance in mathematics and science mirrors that of Grade 8.
- A disappointing feature of the results is that the average score for Grade 9 learners is only around 20 points higher than for Grade 8 learners.

8. Curriculum

- The TIMSS instruments were administered during a period of curriculum change and restructuring.
- During this period, teachers referred to different curricula to determine what and how they taught in their classrooms – NATED 550, C2005, and the RNCS.
- The philosophy underpinning the restructured curriculum was that of an outcomes-based education.
- The official curriculum in 2002 was C2005, and this was characterised by an under-specification of basic knowledge and skills in all learning areas, including mathematics and science.
- South Africa is one of the countries where there is the least overlap with the TIMSS assessment frameworks. While this may have had an effect on achievement scores, analysis of performance on topics teachers said had been covered revealed scores as remaining very poor, with learners achieving only around 20 per cent correct on those items.

9. Learners

Home background

- About one-tenth of South African learners had parents who had completed university or a university-equivalent education, while approximately 30 per cent of learners had parents with no more than a primary education.
- About 10 per cent of South African learners had more than 100 books in the home and about 40 per cent (one of the highest percentages in this category in the international dataset) had fewer that than 10 books in the home.
- Eighteen per cent of South African learners indicated that they ‘always’ speak the language of the test at home, and 15 per cent indicated that they ‘never’ speak the language of the test at home.
- These three resources (parental level of education, the educational resources in the home, and the extent to which the language of the test is spoken at home) were examined to establish what effect they had on mathematics and science achievement scores. The findings indicated that, within the country, the learners who had these resources performed better than those who did not.
- Comparisons across countries revealed a new dimension. Even when these resources (high parental education, and so on) are in place, the South African TIMSS mathematics and science average score for this group of learners is lower than the corresponding groups’ scores in other countries.
- None of these factors on its own can explain performance – it is an examination of the interaction of many factors, embedded within a context, that will generate hypotheses of why performance may be high or low.

Attitudes

- In general, the attitude of South African learners to mathematics and science is positive – they have high self-confidence; they enjoy and value the subjects.
- The responses of learners to questions on attitudes could, however, be socially desirable answers, and there is a need to probe further to determine the ‘real’ attitudes of learners.
- Internationally, and in South Africa, no significant variations in achievement scores were detected between learners who indicated high positive attitudes to mathematics and science and those who did not.

10. Science and mathematics teachers

Profile of the teachers

- The majority of mathematics and science teachers were aged between 30–39, and their average teaching experience was 11 years (for mathematics teachers) and 10 years (for science teachers).
- In South Africa, about 40 per cent of mathematics learners and 50 per cent of science learners were taught by female teachers.
- Over 95 per cent of the TIMSS learners were taught by mathematics and science teachers who indicated that they had completed a post-secondary qualification.
- Around two-thirds of mathematics and science learners were taught by teachers who indicated that they had at least three years of teacher training and that the initial training included either mathematics or science. These teachers can be classified as qualified and knowledgeable in their subject matter.
- Internationally, most teachers have at least a four-year degree as their teaching qualification. The comparison with an international cadre of TIMSS teachers showed South African mathematics and science teachers to be one of the least qualified groups.

Professional development courses

- Internationally, about half the learners were taught by teachers who indicated that they had participated in professional development activities in the past two years.
- The type of professional development activities that most teachers (internationally) participated in related to mathematics or science content and pedagogy.
- The percentage of South African teachers who attended professional development activities was higher than the international average.
- The type of professional development activities that over half the South African teaching group were involved in related to content, curriculum, assessment, and improving critical thinking.
- It is surprising that there was a relatively low percentage of teachers reporting on professional development activities relating to mathematics or science pedagogy or instruction, given that C2005 introduced a different way of organising classroom activities.

11. Classrooms

Class size

- The South African average class size of 45 is the second highest of all TIMSS participants.
- Just over half the South African learners were in classes where there were more than 41 learners in the class.
- Within the country there was a slight association, as expected, between mathematics and science achievement scores and class sizes – the scores were higher when the class size was smaller.

Textbooks

- Internationally, about two-thirds of mathematics teachers, and just over half the science teachers, reported using the textbook as the primary basis for their lessons; the remaining third using the textbook as a supplementary resource.
- In South Africa, the pattern was reversed: one-third of mathematics and science teachers reporting that they used textbooks as the primary basis for lessons, and two-thirds using it as a supplementary resource.

12. Schools

Socio-economic status

- In South Africa, 85 per cent of learners were in schools with more than 50 per cent economically disadvantaged learners. Five per cent of learners attended schools where there were fewer than 25 per cent economically disadvantaged learners.
- Internationally, the average mathematics score for learners in schools with few economically disadvantaged learners was 496; in schools where more than 50 per cent came from economically disadvantaged homes the score was 439 – representing a difference of 57 scale points.
- In South Africa, the average mathematics score for learners in schools with few economically disadvantaged learners was 479; in schools where more than 50 per cent came from economically disadvantaged homes the score was 237. These figures point out the advantage held by economically advantaged learners – their scores were double those of their disadvantaged counterparts.
- In South Africa, economic disadvantage has a severe impact on achievement scores.

School resources, climate and attendance

- About 40 per cent of learners attended schools that teachers and principals classified as having a low resource base for mathematics and science teaching and learning.
- About half the learners attended schools rated by teachers and principals as having a low school climate
- Forty-four percent of learners attended schools rated by teachers and principals as having low school and class attendance.
- The school conditions for about half the learners does not seem to be conducive to experiencing high quality teaching and learning.

Implications

Given the above findings from TIMSS 2003, what then are the implications? The following sections examine some of the implications of TIMSS 2003 for future South African research, policy and practice in education.

Analysis of achievement scores within the country, and a comparison of these scores across several countries, highlights the fact that no single cause can be cited as an explanation for the performance of South African learners. The analysis is conjunctural – a combination of several factors (acting together within particular social, economic, historical and cultural contexts) produced the kinds and levels of performances observed. However, the analysis highlights several leverage points that could be used to raise mathematics and science performance in schools.

1. Improving performance: improve the school

The performance level of learners in mathematics and science in South Africa is very low. However, this poor performance does not exist in isolation; it reflects the inequalities many learners are confronted by within the education system itself. The main challenge for South African education is to improve this system; the aim being, for the purposes of this report, to increase the (currently poor) average achievement scores in the mathematics and science learning areas. In addition, the distribution of scores needs to move from its present postion – skewed to the left – towards a more normal distribution curve.

The performance scores for schools categorised by ex-racial departments show large variations between learners from different social classes and economic backgrounds. Rather than wait for social conditions to change for the better, a better alternative might be to consider the education system itself (its institutions, resources, and so on) as a leverage point for effecting such change. In poorer communities, schools enact a particularly important service in the provision of educational inputs. As outlined in Chapter 10, the role the school plays in determining or shaping the life trajectories of its learners is critical, as it is very often the main, or only, institution capable of fulfilling this function in less advantaged communities.

An important strategy for the improvement and change of score distribution is to increase the number of South African public schools producing good results. Performance is stratified along race and class lines – performance in much better in ex-HoA schools, which are, typically, better resourced and located in areas of higher socio-economic status. African schools face a daunting task in improving their learners' performance. Not only are these schools located in areas of poor socio-economic status (itself a reason behind poor learner performance at school), but they also suffer from the migration of their better performing and resourced learners to higher achieving, more affluent schools.

To facilitate higher national performance, the strategy would be to identify African schools that perform well, then set up an appropriate intervention programme for them. The programme's aim(s) would be to improve the schools' environment and climate; provide more resources for the teaching of mathematics and science; and ensure that there are knowledgeable and competent teachers in place. Higher performing schools are targeted initially because it is likely that only minimal intervention will be needed to increase their performance.

To improve the performance in all schools, the strategy would be; firstly, to ensure that the school environment and climate improves and that there is good school and class attendance. Establishing a good school climate should help improve performance in all learning areas; after this, it will then be possible to focus on issues directly related to mathematics and science.

The key strategy for the improvement of mathematics and science performance is whole-school development, starting with a few targeted sites then gradually expanding the number of schools.

2. Quality of the professional development courses

South African teachers attend a high number of professional development courses. These courses (offered by the Ministry of Education, universities, and non-governmental organisations) are an opportunity to provide a high quality input, and something which could facilitate improving the classroom teaching and learning. Given that this is a high-cost opportunity (the programme costs and the cost of having teachers away from the classroom) and that, so far, there is no clear evidence of the impact these courses have on performance, much more attention must be given to the quality of this intervention. Professional development courses need continual evaluation to ensure a quality input. Furthermore, it would be necessary to measure the affect these courses have upon the classroom, bearing in mind that inputs of this, or any, nature must be directly aimed at improving learner knowledge and skills.

3. Teaching qualifications

The longer-term objective of (and challenge to) the education system should be to raise the qualification of the mathematics and science teachers to the equivalent of a four-year university degree. However, the immediate challenge is to ensure that the one-third of teachers who teach mathematics and science without possessing the appropriate knowledge and skills be given the requisite training and qualifications. A parallel challenge is to offer professional development courses introducing teachers to the new curriculum.

While it is acknowledged that the training will take place over a period of time, it is crucial for investments in teacher development to be of high quality; furthermore, the return on such investments must be better than it is at present.

4. Class size

An objective of the South African education system must be to reduce the class size from the present average of 45. To achieve this will require substantial investment in financial and human resources – that is, getting more classrooms and attracting new mathematics and science graduates into the teaching profession. The Ministry of Education should develop both medium- and long-term strategies for this purpose.

5. Language of teaching and learning

There is an observable relationship between learners' lower achievement at school and the fact that they do not speak the language of the test items at home. However, as mentioned elsewhere in this report, there is a complex set of several factors affecting performance in the classroom. Therefore, the impact language proficiency has on achievement scores needs to be seen in relation to these other determining factors.

Comparison of South African scores with other countries' scores, using the category of 'language spoken', suggests that language factors are embedded within other factors – socio-economic variables, the nature of teaching and, importantly, the appropriate level of cognitive demand in classroom interactions. Noting this, it is thus crucial that teaching quality and the cognitive demands made of learners are of a sufficiently high standard, and target language proficiency of learners.

6. Resources

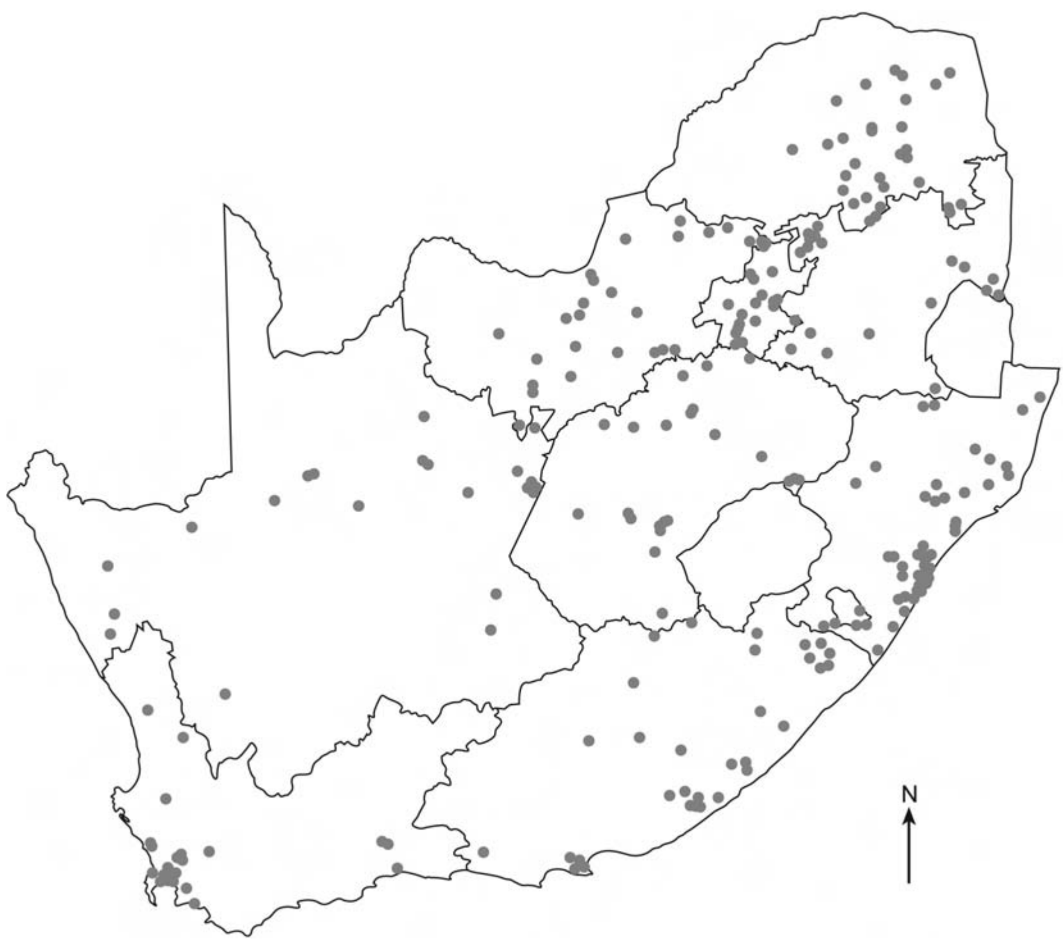
Teachers can be supported in the classroom with the provision of high quality teaching materials. There should be textbooks for learners, paralleling what is taught in classrooms, enabling them to work independently.

7. Participating in international and national systemic studies

It is important for South Africa to participate in studies that incorporate the ability to externally benchmark performance. The choice of which cross-national study to participate in rests on two factors: its benchmarking potential, and the likelihood that it will produce a normal distribution of scores – so allowing for the generation of a model to explain performance. In addition to eliciting information from large-scale, paper-and-pencil tests, studies examining what happens inside classrooms – the teaching and learning of mathematics and science and what learners know, and can do – are also needed.

TIMSS is conducted every four years. The next study (TIMSS 2007) involves data-collection in southern-hemisphere countries at the end of 2006. The South African education system has undergone radical restructuring in its recent past, as several initiatives and interventions have been introduced – each one sharing the common objective of improving teaching and learning in all areas of the curriculum, but especially in mathematics and science. Bearing in mind the strain this intervention has put upon the education system (and, more pertinently, the educators themselves), it is recommended that South Africa does not participate in TIMSS 2007, but rather does so in 2011, as this will allow the intervention programmes to become embedded within the education system. This achieved, it would then be more reasonable to measure South African performance in TIMSS 2011 to see how far the country has progressed.

APPENDIX 1: GIS plot showing South African schools that participated in TIMSS 2003



APPENDIX 2: Profile of schools sampled in Grade 8 TIMSS, by ex-racial department

	Ex-DET	Ex-HoR	Ex-HoD	Ex-HoA	Total
Eastern Cape	30	2		1	33
Free State	23	1		1	25
Gauteng	16	2	2	3	23
KwaZulu-Natal	37	1	7	1	46
Mpumalanga	22			2	24
North West	24			1	25
Northern Cape	5	12		8	25
Limpopo	31				31
Western Cape	1	15		7	23
Total	189	33	9	24	255

APPENDIX 3: Profile of learners taking the TIMSS tests in Afrikaans

	Ex-DET	Ex-HoR	Ex-HoA	Total
Gauteng			32	32
Mpumalanga			31	31
North West	35			35
Northern Cape	42	236	122	400
Western Cape		414	128	542
Total	77	650	313	1 040

APPENDIX 4: 2002 South African public school statistics

Province	Learners	Educators	Schools	L:E ratio	L:S ratio
Northern Cape	194 062	6 334	459	30.6	423
Free State	693 213	21 947	2 281	31.6	304
North West	887 649	29 451	2 247	30.1	395
Western Cape	915 270	25 225	1 460	36.3	627
Mpumalanga	903 789	24 870	1 856	36.3	487
Gauteng	1 482 253	44 651	1 915	33.2	774
Limpopo	1 816 200	55 155	4 561	32.9	398
Eastern Cape	2 064 927	64 974	6 150	31.8	336
KwaZulu-Natal	2 680 993	71 624	5 560	37.4	482
TOTAL	11 638 356	344 231	26 489	33.8	439

*Notes: * L:E – learner-to-educator*
*** L:S – learner-to-school*

Source: DoE 2002c

APPENDIX 5: Socio-economic indicators by province

Indicators	Year	EC	FS	G	KZN	L	M	NW	NC	WC	SA
Area (km^2)	2001	170 616	129 437	21 025	91 481	116 824	82 333	363 389	118 710	129 386	1 223 201
Population density (persons per km^2)	2001	39	21.8	385	100.1	47.1	37.8	2.5	30.5	33.7	36.1
Population (000's)	2001	6 657	2 819	8 094	9 160	5 497	3 109	891	3 621	4 354	44 202
Urban population	2001	2 343	2 018	7 859	4 415	781	1 309	621	1 394	3 897	25 593
Urban population as % total population	2001	35.2	71.6	97.1	48.2	14.2	42.1	69.7	38.5	89.5	57.9
Non-urban population	2001	4 314	801	235	4 745	4 716	1 800	270	2 227	457	18 609
Non-urban population as % total population	2001	64.8	28.4	2.9	51.8	85.8	57.9	30.3	61.5	10.5	42.1
HDI	2003	0.62	0.67	0.74	0.63	0.59	0.65	0.61	0.69	0.77	0.67
Poverty rate (%)	2000	48.0	48.0	12.0	26.0	38.	25.	37.	35.	12.	28.5
Adult literacy (%)	2003	77.6	89.8	96.7	90.5	78.7	80.3	74.0	84.6	94.6	86.9
Life expectancy (years)	2003	50.5	48.1	51.2	43.6	51.2	46	49.3	56.8	61.5	49.2
Unemployment rate (exp. def.) (%)	2002	39.2	40.9	35.6	46.7	55.1	41.7	46.3	41	25.5	40.9
Access to electricity (%)	2001	45.8	82	84.1	62.6	56.3	74.6	74.8	77.7	88.1	65.2
Access to water (%)	2001	62.4	95.7	97.5	73.2	78	86.7	86.2	96.6	98.3	84.5
Access to sanitation (%)	2001	69.2	90.3	96.4	83.8	76.7	89.7	90.4	88.8	92.3	86.4

Notes: Access refers to:

- *Electricity: electricity directly supplied by an authority for lighting purposes*
- *Water: access to piped water in the dwelling, piped water on site or access to a public tap*
- *Sanitation: access to a flush or chemical toilet or pit latrine*
- *Refuse removal: refuse removed by a local authority at least once a week or less often*
- *Telephones: access to a telephone in the dwelling or access to a cellular phone*
- *Poverty is measured as household consumption expenditure at R800 or less per month*

EC = Eastern Cape; FS = Free State; G = Gauteng; KZN = KwaZulu-Natal; L = Limpopo; M = Mpumalanga; NW = North West; NC = Northern Cape; WC = Western Cape.

Sources: UNDP 2003; Stats SA 2000; 2001; 2002

APPENDIX 6: Schools in the TIMSS 2003 Grade 9 sample

	Ex-DET	Ex-HoR	Ex-HoD	Ex-HoA	Total
Eastern Cape	29	2		1	32
Free State	21	1		1	23
Gauteng	14	1	2	1	18
KwaZulu-Natal	35	1	6	1	43
Mpumalanga	22			2	24
North West	23			1	24
Northern Cape	4	9		7	20
Limpopo	32				32
Western Cape	1	14		7	22
Total	181	28	8	21	238

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