MATHEMATICS AND SCIENCE ACHIEVEMENT AT SOUTH AFRICAN SCHOOLS IN TIMSS 2003

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

IEA TIMSS ·2003·

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Dr Vijay Reddy
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