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AUTHOR	Howie, Sarah
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ABSTRACT

The Third International Mathematics and Science Study (TIMSS) is the largest and most ambitious international study of mathematics and science achievement ever undertaken, with more than 500,000 school students in 45 countries being tested in mathematics and science at five different school year levels. South Africa is the first country in Africa to have participated in and successfully completed such a comprehensive international survey in science and mathematics education. This report provides detailed information about TIMSS and highlights the results related to South Africa. Data are presented in 21 tables and charts. (Contains 17 references.) (ASK)

MATHEMATICS AND SCIENCE PERFORMANCE IN THE MIDDLE SCHOOL YEARS IN SOUTH AFRICA

A Summary Report on the performance of South African students in the Third International Mathematics and Science Study

TIMSS SOUTH AFRICA

Sarah Howie

TIMSS SA Project Team:
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TIMSS-SA

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Pretoria

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Executive summary

Introduction

Concern has been growing around the world, since the 1960s, that investments in education need to be related to the outcomes (results) of education, which, in turn, are seen as a substantial contribution to a country's economic prosperity and general well-being. As the twenty-first century approaches, the demand for mathematical, scientific and technological understanding and expertise is greater than ever before. Consequently, countries around the world have been looking for methods of making teaching and learning in these areas more effective in their different school education systems. International studies are a way of providing information on student achievement and factors that may play a role in such achievement.

The Third International Mathematics and Science Study (TIMSS) is the largest and most ambitious international study of mathematics and science achievement ever undertaken, with more than 500 000 school students in 45 countries being tested in mathematics and science at five different year levels (equivalent to Std 2, Std 3, Std 5, Std 6 and Std 10 in South Africa). This involved 15 000 schools around the world and 31 different languages. Quality control procedures were developed to ensure that the tests written by the students were of a suitable quality to ensure the credibility and validity of the study. The same tests were written by the students in the different countries. Detailed sampling procedures were devised for selecting schools and students who would participate in the TIMSS study. These procedures were designed to ensure that a representative sample of students was selected from each country. The way in which the procedures were implemented was monitored.

TIMSS was preceded by two earlier mathematics studies (1964 and 1980-82) and two earlier science studies (1970-71 and 1983-86) (Keeves, 1995), carried out separately from one another. All these studies were smaller than TIMSS in terms of the number of participating students and countries. The International Association for the Evaluation of Educational Achievement (IEA), based in the Netherlands, was also responsible for these studies.

Major research questions guiding TIMSS

The development of the TIMSS was guided by four research questions:

(1) What are students expected to learn?

(2) Who provides the instruction?

(3) How is the instruction organised?

(4) What have students learned?

Each of these key questions suggests a large number of more specific questions, some of which are touched on this summary report and others which will be dealt with in-depth in the detailed reports to be published later.

Students participating in TIMSS

The TIMSS study investigated mathematics and science achievement at three stages of schooling and defined the following three target populations: Population 1, Population 2 and Population 3 (Martin and Kelly, 1996).

Population 1 : the two adjacent grades/standards containing the largest proportion of nine-year-old students at the time of testing.

Population 2 : the two adjacent grades containing the largest proportion of 13-year-old students at the time of testing.

Population 3 : the final year of secondary schooling.

In the context of the South African study, Population 1 was not included owing to the underlying problems with language and the medium of instruction. Population 2 and Population 3 were tested in South Africa. Standard 5 and Standard 6 classes were tested together as one group (as Population 2) and the Standard 10 classes were tested as Population 3. The Human Sciences Research Council conducted this survey in South Africa

This summary report is the first in a series of three reports that will provide information on the Standard 5 and Standard 6 (Population 2) part of TIMSS in South Africa.

Key Aspects of TIMSS

Achievement tests are of primary importance to the TIMSS study. These tests were developed collaboratively by the countries participating in the study and were subjected to extensive trials in pilot studies and field trials. The questions were also reviewed by experts in assessment and in science and mathematics curricula. About a third of the questions required the students to write their own answers, rather than select answers from multiple choice options. Many countries (excluding South Africa) also participated in a performance assessment component, in which students carried out empirical experiments and other investigative tasks.

Comparative studies in education gain more meaning when considered in relation to the educational context in which they occurred. Data on a considerable number of contextual factors, included in various questionnaires, were collected in TIMSS, with the data having been collected from principals, teachers, students and Education Department officials and curriculum experts.

Data collected in South Africa

South Africa is the first country in Africa to have participated in and successfully completed such a comprehensive international survey in science and mathematics education. In South Africa, as mentioned previously, the decision was made to test Std 5, Std 6 and Std 10 students only and not to test the first age group of Std 2 and Std 3 pupils owing to financial constraints and the issue of medium of instruction in the primary schools at this age level. South Africa participated in the achievement testing and the administration of the questionnaires, but not in the performance assessment also owing to financial constraints etc. A randomly selected national sample of schools, representative of all provinces, race groups, urban and rural communities, was identified.

Data from 4 491 Std 6 students from 114 schools and 5 301 students in Std 5 from 137 schools (HSRC, 1995) were included for analysis in the study. The Std 5 and Std 6 pupils wrote the same tests (aimed at the expected developmental level of a 13-year-old child). Std 5 and Std 6 students also completed the same background questionnaires. Other questionnaires containing questions about socio-economic and demographic conditions, that have an impact on the teaching and learning of mathematics and science, were administered to mathematics teachers, science teachers and school principals.

During 1995, Std 10 students were also tested in some 150 classes. In total, about 400 classes participated as the representatives of South African schools. Std 10 students wrote a general paper containing mathematics and science questions and completed a questionnaire. Questionnaires on the prevailing socio-economic and demographic conditions were also sent to the school principal. The results of the Std 10 students (TIMSS Population 3) have not yet been released by the International Study Centre and therefore will not be reported in this summary report.

In addition to the achievement tests, performance assessment and questionnaires, detailed data on curriculum matters were collected. The curriculum was considered, as in previous IEA studies, on a number of levels:

- the intended curriculum, which was the curriculum as specified at national/system level;
- the implemented curriculum, which was the curriculum as interpreted and delivered by the classroom teachers;
- the attained curriculum, which was that part of the curriculum learnt by the students as demonstrated by their achievements and attitudes.

The intended curriculum was measured, on the basis of a set of international criteria, by a local panel of highly qualified and experienced experts in mathematics, science and geography. They analysed the South African syllabi uses, curriculum guides and most used textbooks in mathematics and science (general science, biology and physical science, as well as geography) at Std 2, Std 5, Std 6 and Std 10 levels. The implemented curriculum was gauged from the teachers' responses to the many questions in the questionnaires, particularly with reference to those students they taught in classes sampled for TIMSS. The attained curriculum was measured by the student's performance on the tests.

Highlights of results for Std 5 and Std 6

These highlights reflect only the results of the achievement tests taken from the international reports on TIMSS (TIMSS, 1996) and some preliminary findings drawn from the questionnaires. In-depth analyses and detailed findings regarding the Std 5 and Std 6 results will be released later.

Achievement tests

- South Africa's scores are very low in comparison with those of other participating countries.
- South Africa's results did not display any areas in science and mathematics in which students performed well.
- South Africa's results indicated the lowest overall improvement from Std 5 to Std 6.
- There was evidence of language problems among the students in the international study, including the South African students. The vast majority of the South African students wrote the TIMSS tests in a language that was not their mother tongue.
- The international results indicate that there is a strong link between the home environment and achievement.
- The performance of students on questions covered by the curriculum was much the same as that for the questions not in the curriculum. This was true both for South Africa and nearly all the other countries.
- The study's curricula research indicates that South African science curricula are not in line with those of other participating countries. Only 18 % and 51 % of the TIMSS science questions

were included in the Std 5 and Std 6 curricula respectively. The mathematics curricula were more in line with other countries with 50 % and 79 % of the TIMSS questions being included in the Std 5 and Std 6 curricula respectively (Beaton *et al.*, 1996a).

- It would appear that South African students possess generally inadequate problem-solving techniques.
- It would appear that South Africa students generally have difficulty in constructing their own answers.
- Internationally, the difference in achievement between boys and girls was minimal in mathematics, but pervasive in science. Boys outperformed girls in chemistry (at Std 6 level), physics and earth sciences. However, in South Africa there was no statistically significant difference between the mean test scores of the boys and the girls in either Std 5 or Std 6.
- It is significant that in top-performing countries, classroom size did not appear to influence achievement negatively. In Korea, 89 % of the students were in classes with more than 40 students, whilst in Hong Kong, Japan and Singapore, 90 % of the students were in classes with more than 30 students.

Preliminary findings from the student questionnaires

An initial study by the HSRC of the student questionnaires revealed the following factors:

- Twenty-one percent of the students wrote the achievement tests in their home language.
- The amount of homework reported by the students for both science and mathematics was much lower than the international average for Population 2.

- Surprisingly, the amount of time spent weekly on extra lessons in science and mathematics was not very much less than that spent on homework.
- The international results indicate that there is a strong link between the home environment and achievement.
- The research shows that the South African students had less learning time in classrooms than the students in the top performing countries in TIMSS.
- The average age of SA students in Std 5 was 13,9 years and in Std 6 was 15,4 years. The South African students' average age was the second oldest and only Colombia had older students participating in TIMSS.
- The average number of books reported in the home was far fewer than the international average.
- The number of students who reported that they had their own bedroom in the home was 56 to 59 %, which is surprisingly high in the South African context.
- The percentage of students who felt that they did very well or well in science or mathematics ranged from 74 to 80 %, in spite of the poor performance of the South African students in the achievement tests.
- The percentage of students who felt they needed to do a lot of hard work and studying at home in order to do well in science or mathematics was lower than that in nearly all the other countries. On the other hand, the percentage of students who felt that good luck was needed in order to do well was higher than that in nearly all the other countries. This was in striking

contrast to the results from high- performance countries such as Singapore, Hong Kong, Korea and Japan, where very high percentages of students felt that hard work was important in order to do well.

- The percentage of students reporting that they liked science and mathematics ranged from 65 % to 74 %, which was similar to the percentages in other countries.
- There was a contradiction in the percentages of students who reported that they enjoyed learning science or mathematics, and those who reported that they found the subject boring. For example, 84 % of Std 5 students said they enjoyed learning science, and 39 % found it boring.
- The figures for career choices in the natural sciences are disturbing. In the case of Std 6 students, if students were to choose a career in the natural sciences, 32 % would choose biology, 24 % would choose physics and only 7 % would choose chemistry.

Many of these findings will be analysed in detail to determine the reasons for the results and findings. These in-depth analyses will be published during 1997 in two reports. These baseline data have been collected at a time when South Africa is undergoing an exciting and challenging reform process in education. The timing of the TIMSS study in South Africa could not have been better and will provide some much-needed information to meet the educational challenges that will face this country at the beginning of the 21st century.

List of figures and tables

Acknowledgments

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- The curriculum analysis team who completed an enormous task most willingly, enabling South Africa's participation in the curriculum analysis part of the TIMSS study.
- The fieldworkers contracted by MarkData who collected the data under incredible time pressures and often very awkward circumstances.
- Colleagues in the Group Education, and in the Computer Centre, especially Elsie Venter and the data-capturing ladies, who assisted in crisis times and who made our participation ultimately possible.
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1 Introduction

1.1 Background

In 1995 the Human Sciences Research Council (HSRC) conducted a survey on mathematics and Science among 15 000 South African students from more than 400 primary and secondary schools, as part of the Third International Mathematics and Science Study known as TIMSS. World-wide more than half a million students in 45 countries participated in the project.

This report represents a summary of the international report on TIMSS focusing on South Africa's participation. The achievements of the South African students are looked at from a national and an international perspective. This report will be followed by two other reports that will investigate issues highlighted in the present report and provide a deeper analysis of TIMSS in South Africa as a whole.

Concern has been growing around the world, since the 1960s, that investments in education need to be related to the outcomes of education, which, in turn, are seen as being able to make a substantial contribution to a country's economic prosperity and general well-being. As the twenty-first century approaches, the demand for mathematical, scientific and technological understanding and expertise will be greater than ever before. Students at the forefront of developments in the future will require very high levels of mathematical and scientific skills. These students will need to develop critical thinking, processing and interpreting skills far beyond those required a decade previously. Competence in mathematics and science will be crucial, together with these skills, as students leave school and enter higher education and the workplace.

With the need for populations to be better educated (in South Africa's case the basic need for literacy and numeracy) and shrinking national budgets, countries around the world have been looking for methods of making teaching and learning in these areas more effective. International studies are a means of providing information on student achievement and the factors that play a role in such achievement. The challenge will always be to learn more about effective teaching and learning, both for educators and policy-makers in the education field.

In South Africa, poor matriculation results continue to dominate the news at the end of every school year. 1995 had the best school attendance figures in years, but nonetheless poor results were evident once again. The story was repeated in 1996 despite changes and reforms in the Department of Education. The reasons for the failure are varied, however whatever changes are implemented, they need time to make an impact. *A system is required whereby the impact of these changes can be monitored. This concept of monitoring has long been recognised internationally and has been adopted by other countries introducing reform into their education systems.*

TIMSS is the largest and most ambitious international study of mathematics and science achievement at school level ever undertaken. It is the first time that mathematics and science studies have been combined as an integrated study. TIMSS is also the largest comparative study of its kind conducted under the auspices of the International Association for the Study of Educational Achievement (IEA), which is based in the Netherlands. The IEA is an independent international grouping of national research institutions and governmental research agencies. Its primary purpose is to conduct large-scale comparative studies of educational achievement, with the aim of gaining an in-depth understanding of the effects of policies and practices within and across systems of education. The IEA has conducted more than 15 studies of achievement involving groups of different countries since its inception in 1959.

The IEA officially launched TIMSS in 1994. It was undertaken in more than 60 countries across the world. Highly developed countries and developing countries, from both the northern and the southern hemispheres were included. Of the 63 countries that started the study, only 41 completed it. South Africa was the only country in Africa to complete the study.

TIMSS was developed to assess the national curricula, school and social environment and achievement in science and mathematics in the participating countries and different systems of education around the world. TIMSS tests were designed to measure mathematics and science achievement in order to help inform governments, policy makers and educators about the mathematics and science proficiency of their students at key points in the educational process. The questionnaires were aimed at collecting information about factors related to students' learning of mathematics and science.

The first part of this report gives an overview of the entire project of TIMSS, including its conceptual framework, various components and the design of the achievement instruments. The second part of the report, Chapters three and four, summarises the science and mathematics achievement of the South African students in standards five and six.

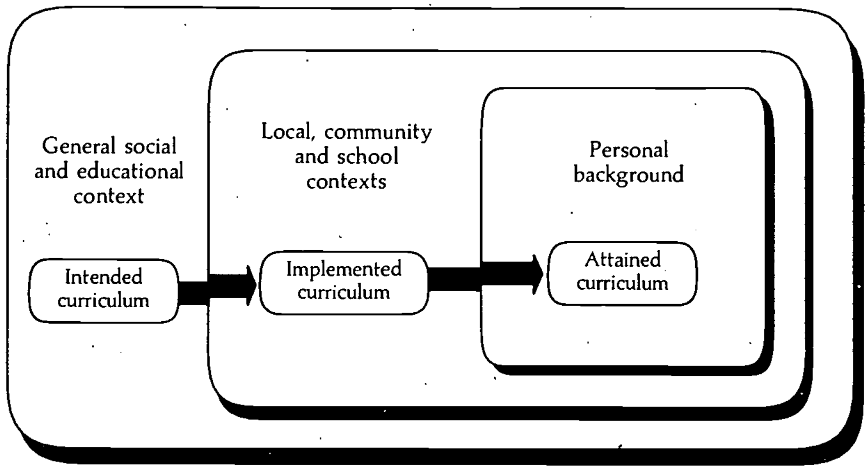
This summary report is the first in a series of reports. The other reports will contain in-depth analyses and more technical detail, focusing on South Africa's participation in TIMSS.

1.2 Conceptual framework for TIMSS

IEA studies traditionally have recognised the importance of the curriculum as a variable for explaining differences among national school systems and for accounting for student outcomes. These studies represented an effort to understand education systems and to make valid comparisons between them. The curricula and teaching practices were investigated and compared with the student outcomes. These three factors became the focus areas for TIMSS. It was believed that differences in achievement could be explained in terms of variations in curriculum, teaching practices and other variables. It was also hoped that the study would help countries to evaluate national curricula and provide a research basis for future national curriculum reform.

The conceptual model for TIMSS was derived mainly from the models used in earlier IEA studies, especially for SIMS (Second International Mathematics Study)and SISS (Second International Science Study). In this model three "levels" of curriculum are envisaged (see Figure 1.1), intended, implemented and attained. The educational environment, made up of a variety of factors, should be understood from the perspective of these three curriculum levels. It is believed that there are factors outside of formal schooling that affect the student's achievement. There is a unique set of contextual factors that influence the educational decisions for each level of the curriculum (Martin and Kelly, 1996).

Figure 1.1 TIMSS conceptual framework



Robitaille, *et al.*, 1996

Robitaille's model, adopted by TIMSS as its conceptual framework, provides a rationale and context for the key research questions in TIMSS. Four questions are central to the study:

(1) What concepts, processes and attitudes regarding mathematics and science have students learnt and what factors are related to their opportunity to learn these concepts, processes and attitudes?

(2) How do education systems differ in the intended learning goals for mathematics and science, and what characteristics of education systems, schools and students are related to the development of these learning goals?

(3) What opportunities are provided for students to learn mathematics and science, how do instructional practices in

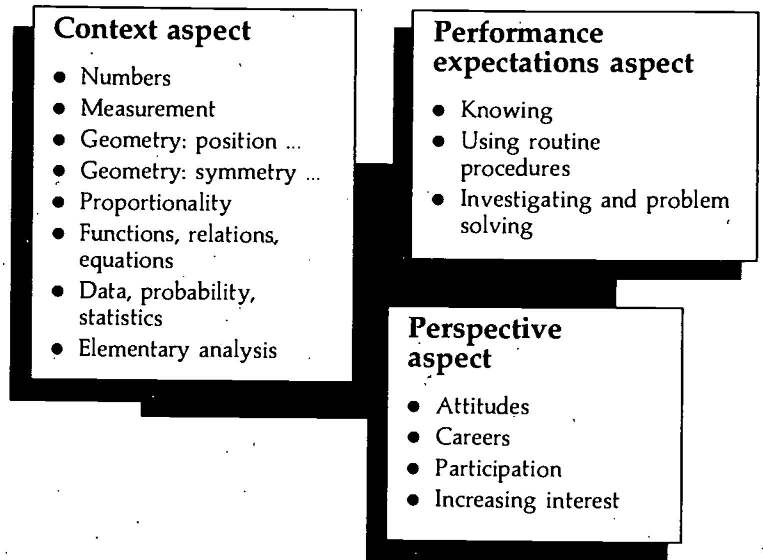
mathematics and science vary among education systems, and what factors are related to this variation?

(4) How are the intended, implemented and attained curricula related with respect to the context of education, the arrangements for teaching and learning and the outcomes of the education process?

1.3 TIMSS curriculum framework

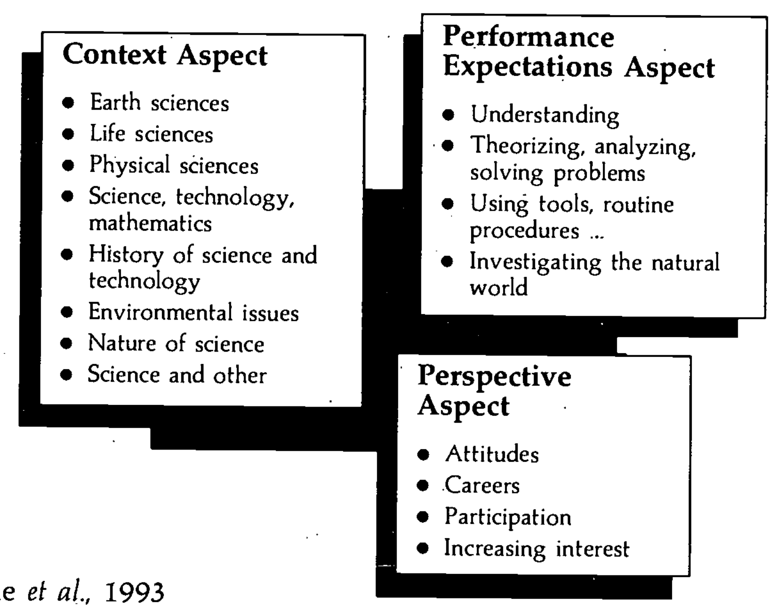
The concept of the curriculum as a variable requires a framework for the description of the three levels of the curriculum. In the context of the TIMSS curriculum framework (Robitaille *et al.*, 1993), the curriculum consists of the concepts, processes and attitudes of school mathematics and science intended for, implemented in, and attained during students' schooling experiences. This framework allows for a given assessment question (item) or proposed teaching activity to be categorised in detail. They can be categorised in terms of subject matter (e.g. mathematics), performance expectations (e.g. understanding of content) and perspectives or context (e.g. at school). The detailed categories within the science and mathematics frameworks differ, but the structure and rationale of the two frameworks are the same, allowing for comparisons across the two curriculum areas (see Figure 1.2 and Figure 1.3).

Figure 1.2 Three aspects and major categories of the mathematics framework



Robitaille *et al.*, 1993

Figure 1.3 Three aspects and major categories of the science framework



Robitaille *et al.*, 1993

The content aspect represents the content of school mathematics or science, depending on the framework selected. The performance expectations aspect is the cognitive (thinking) behaviour dimension in earlier IEA studies, which has been reconceptualised. The aim of this particular aspect is to describe the many kinds of performances or behaviours that one would expect from students answering a given test question. The perspectives aspect relates to the analysis of documents such as textbooks. This aspect allows the components of the curricula to be categorised according to the nature of the discipline/subject field of such documents (Martin and Kelly, 1996).

Each of the three aspects (content, performance expectations and perspectives) is divided into a number of categories and subcategories. The TIMSS framework can be described as a multi-aspect, multi-category system where a test question can be related to any number of categories within each aspect or aspects. An achievement question must therefore be associated with numerous combinations of aspect categories in the TIMSS framework.

It is accordingly believed that this framework is well suited to deal with the complexity of student activities emerging from various national reforms of mathematics and science. It is also suited to the complex, integrated performances expected from students in the new forms of assessment emerging together with the curricular reforms.

1.4 Student populations in the TIMSS

TIMSS identified and selected three focus areas in the school education system. In the international context these are referred to as Population 1, Population 2 and Population 3. Population 1 consisted of students in those grades/standards containing the largest proportion of nine-year-old students. Population 2 consisted of students in the two adjacent grades/standards containing the largest proportion of 13-year-old students. Population 3 consisted of students in their last year of formal schooling. The age of the students was taken as the age the students were when they wrote the achievement test (Martin and Kelly, 1996).

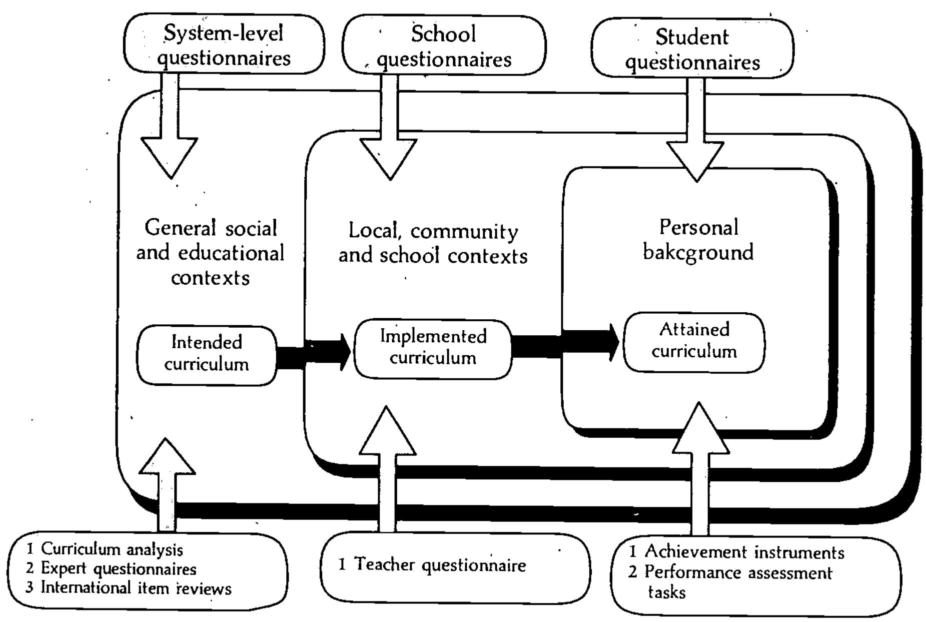
In the context of the South African study, Standards 2 and 3 represented Population 1. At the time of the investigation mother tongue was the medium of instruction up to Std 2. This population was not included as no resources (human and financial) were available for translations into other languages. Standard 5 and Standard 6 represented Population 2 and Standard 10 represented Population 3. Standards 5, 6 and 10 were all tested in South Africa, allowing South Africa to be included in the Population 2 and Population 3 of TIMSS.

The students in Std 10, who were in the selected schools, were tested regardless of the subjects they were studying. Internationally, those Population 3 students who were specialising in mathematics or physics were identified as subgroups and were given specialised tests. In South Africa, students do not specialise to this degree and therefore the Std 10 students who were tested, wrote the general science and mathematics literacy achievement test; and no specialised tests were written.

1.5 General design of TIMSS

The TIMSS research was conducted at three levels: the curriculum analysis level, the achievement tests level and the questionnaires level. Figure 1.4 illustrates the instruments (achievement tests and questionnaires) that were used.

Figure 1.4 The relationship of TIMSS data collection instruments to the conceptual framework



Robitaille *et al.*, 1996

Four questionnaires were administered at the national (system) level at various times in the course of the study. Two of these questionnaires focused on the organisational structure, courses, demographic and teacher credentials, and were completed by people knowledgeable about the structure of their education system. Two other questionnaires were for curriculum specialists, seeking information on the national level curriculum plans, reforms, issues and policies with respect to mathematics and science curricula. Both the questionnaires were completed either by a mathematics or a science curriculum specialist. The "specialist" questionnaires provide important information on present and future curricular goals and content changes — information not contained in curriculum guides. Questions were asked about recent curriculum innovations, national assessment practices, instructional goals, the availability of textbooks and teachers' manuals and policies on curriculum guides, assessment and student tracking. The purpose of these questionnaires was to gain an understanding of the contexts of the education systems, and their impact on the intended and implemented curricula. National level data were supplemented with data collected at school level in order to provide information on how education might vary within a country.

A school questionnaire was designed for the principal of each sampled school. The results from these questionnaires should give a good idea of the kinds of schools in the education system. Among the topics addressed in this questionnaire were enrollment, demographic, subject selection, and administrative, curricular, budgetary and social issues. The questionnaires administered to the primary and secondary schools were similar in content, with some questions being modified or omitted.

TIMSS developed three teacher questionnaires to obtain information on the curricula implemented at school. These included two questionnaires at Population 2 level, one of which was designed for the mathematics teachers and one for the science teachers. The other questionnaire was at Population 1 level; Population 3 had no teacher questionnaire. The questionnaires included five topics: teacher's background, attitudes to teaching and learning, expectations for students, instructional practices, and opinions on mathematics and science education.

TIMSS also developed three different questionnaires for students, although they were similar in organisation and content. There was one for each TIMSS population group tested. They included questions on the student's background, opinions and attitudes to mathematics and science.

1.6 The TIMSS achievement instruments

Traditionally, large-scale surveys conducted by the IEA and other bodies have used multiple-choice questions.. Tests using the multiple-choice format are very popular as the test conditions can be standardised, the cost is low and they can be machine scored. However, recently there has been growing awareness among educators that some important achievement outcomes are either difficult or impossible to measure using the multiple-choice format. Communicating mathematical or scientific findings or constructing a mathematical proof requires skills for which the multiple-choice questions appear to be unsuitable. It was therefore decided that TIMSS should employ a variety of questions to increase the coverage of the desired outcomes of school mathematics and science education. Four different types of questions were included in the pool of TIMSS questions: multiple-choice questions, short answer questions, extended answer questions and performance tasks. [In TIMSS the short answer and the extended answer questions were referred together as Free Response Items]. As in all other countries, these achievement tests were written in the students' language of instruction, which for South African students in Stds 5, 6 and 10 was English or Afrikaans.

The multiple-choice questions consisted of a question and four or five choices of answer, of which only one was the correct answer. Students were encouraged to choose the answer they thought was the best when they were unsure about an answer.

In both the short answer and the extended response questions, students were required to write their responses and these were coded using a set of two-digit codes developed for use in TIMSS (Martin and Kelly, 1996). The first digit was coded for correctness of the answer and the second digit was a code to identify the qualities of the students' responses. For the short answer items, the students were required to write a brief verbal or numerical answer. The items were coded correct or incorrect, and the students were not required to show details of the approach they used or the calculations they performed on such questions.

The multiple-choice, short answer questions and extended response questions were randomly distributed, in different groups or clusters of questions, throughout the test booklets.

The performance tasks were designed to assess some of the skills and abilities that could not be assessed readily by a written test. Tasks were performed in small groups and these groups were observed by the researchers in participating countries. However, South Africa did not use this form of assessment owing to financial and other constraints.

2 Sampling and administration of the TIMSS Population 2 study

2.1 Sampling

The sampling procedure was strictly controlled and was designed by the international study group to ensure the statistical validity of the study, by providing a random sample of students that was representative of the country as a whole.

In South Africa, for Population 2 a random sample of schools was drawn from all schools that had more than 40 students in Std 5 in 1991. This was done as follows (Claassen, 1996):

- For the Western Cape, schools were arranged from the smallest to the largest according to the number of students in Std 5;
- immediately below this list, a similar list for the Northern Cape schools was compiled, but this time arranged from the largest to the smallest in terms of Std 5 student numbers;
- this process was continued for the other seven provinces;
- an appropriate interval was then chosen so that 150 schools were uniformly spaced along the list;
- a random number was generated to select the first school, after which the remaining 149 followed automatically;
- in each of the selected schools one of the Std 5 classes was randomly selected and the tests administered to that class only;
- the same procedure was followed for Std 6.

Table 2.1 Distribution of schools in South Africa

Province	Std 5	Std 6
Western Cape	12	10
Northern Cape	3	2
Free State	9	11
Eastern Cape	24	21
Kwazulu/Natal	33	33
Mpumalanga	11	13
Northern Province	26	27
Gauteng	19	21
North West	13	12
Total	150	150

(Claassen, 1996)

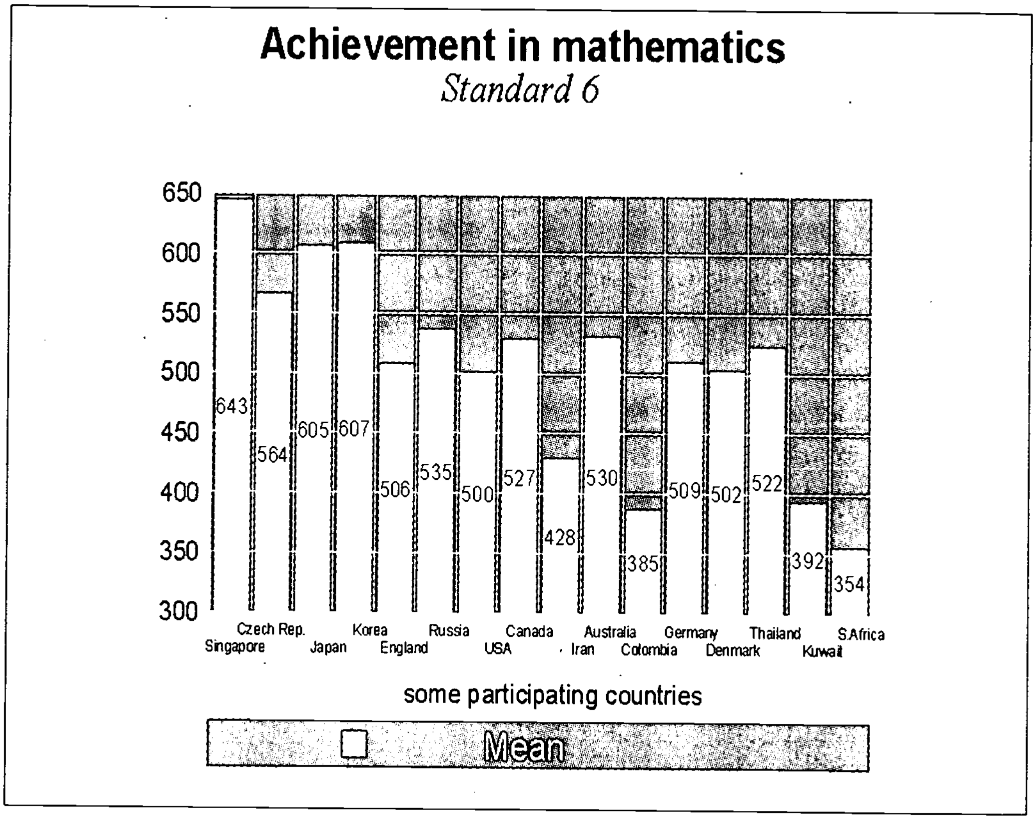
2.2 Administration of Population 2 in South Africa

The achievement test was administered between August and December 1995. The scoring of the free response questions was completed in January 1996. The total number of schools selected for participation in the study is shown in Table. 2.1 above. Some of the selected schools were unable to participate for various reasons. The actual number of classes participating in the study whose scores were reflected in the international reports was 251, of which 137 were Std 5 classes and 114 Std 6 classes. The total number of participating students whose scores were included in the international study was 5 301 for Std 5 and 4 491 for Std 6. The scores of the pupils were weighted so that the resulting mean score obtained from the study would be an unbiased estimate of the population mean.

3 International comparison of the achievement of South African students in mathematics

3.1 Overall performance in Mathematics in Std 6 and Std 5

Figure 3:1 Distributions of mathematics achievement for Std 6

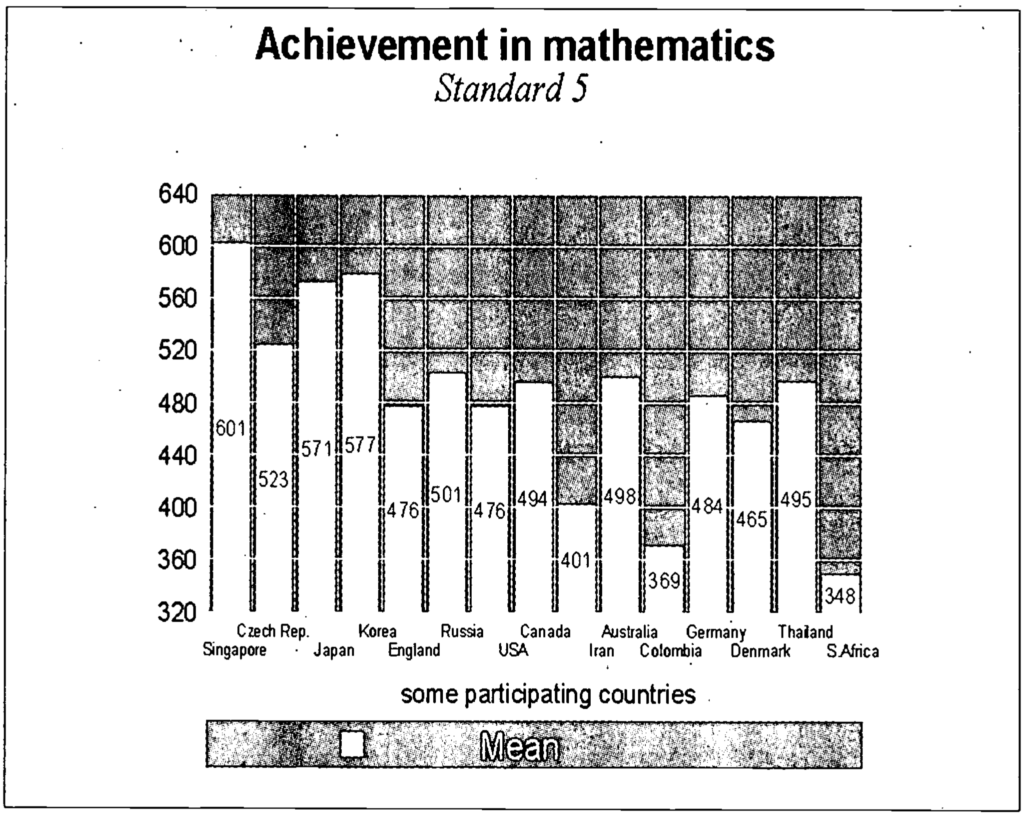


Figures 3.1 and 3.2 show the mean scores for Std 5 and Std 6 internationally respectively. The scale used when computing the finals scores was based on an 800 point scale. The score on the scale used by the TIMSS study in their calculation, was a score computed from the Item Response Theory, using weighting factors

determined by the relative difficulty of questions. The scaling also allowed the student performance to be summarised on a common scale even though individual students responded to different questions in the test according to the rotation design of the test administration (Robitaille, *et al.*, 1996).

The results show a substantial difference in achievement between the top and bottom-performing countries. As shown in both figures, South Africa performed poorly, achieving a score of 348 for the Std 5 pupils compared to the international mean of 484. The Std 6 pupils fared little better achieving a score of 354, compared to the international mean of 513 (Beaton *et al.*, 1996a).

Figure 3.2 Distributions of mathematics achievement for Std 5



3.2 Achievement differences in Mathematics between Std 5 and Std 6

Figure 3.3 Achievement differences in mathematics between Std 6 and Std 5

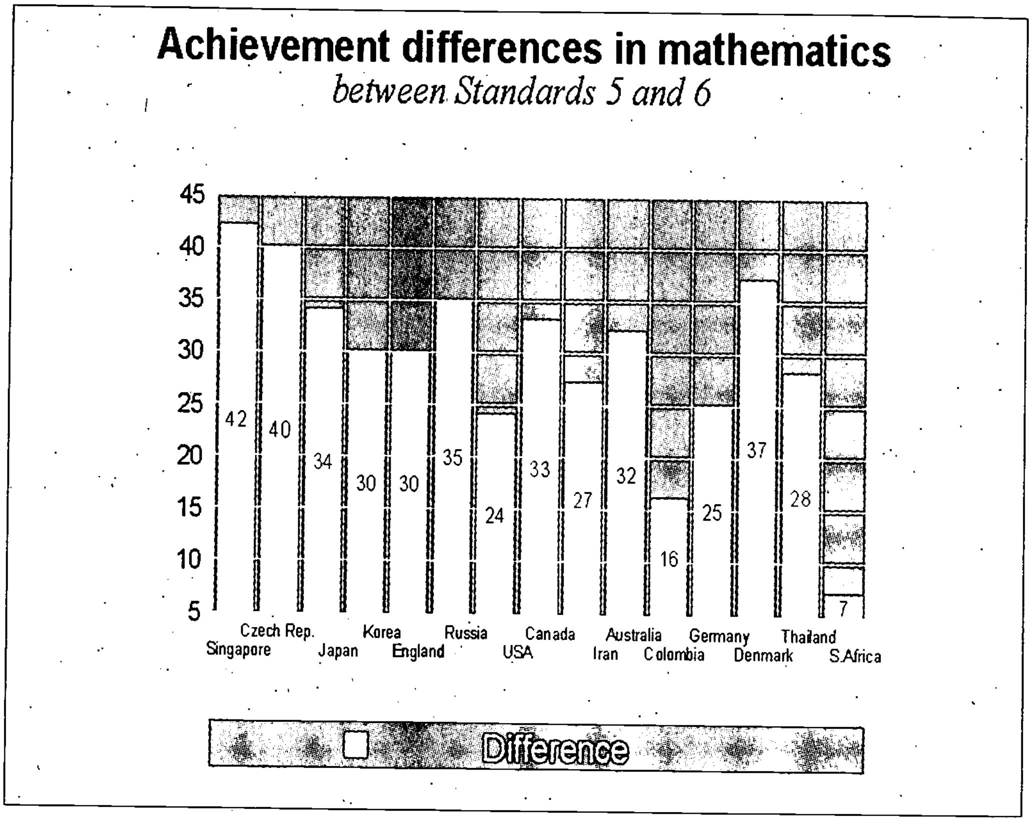
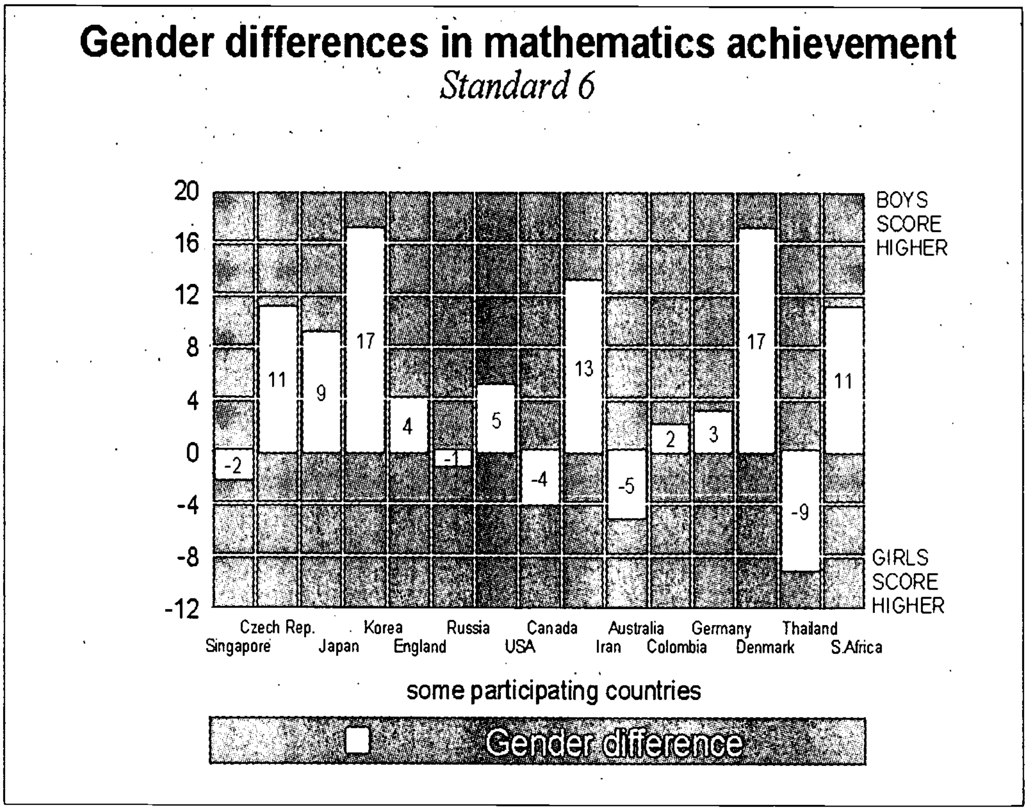


Figure 3.3 shows differences in mean achievement between the two grades tested in each participating country. The increase between grades varies between countries. South Africa's difference between the performance of the Std 5 and Std 6 students is very slight. It is in fact the lowest improvement in performance (just 7 points) between the grades of all the participating countries. Out of all the countries, Lithuania, France and Norway showed the greatest improvement between the grades. In the figure above, Singapore

and the Czech Republic showed the biggest difference and Colombia and South Africa displayed the least improvement between the grades (Beaton *et al.*, 1996a).

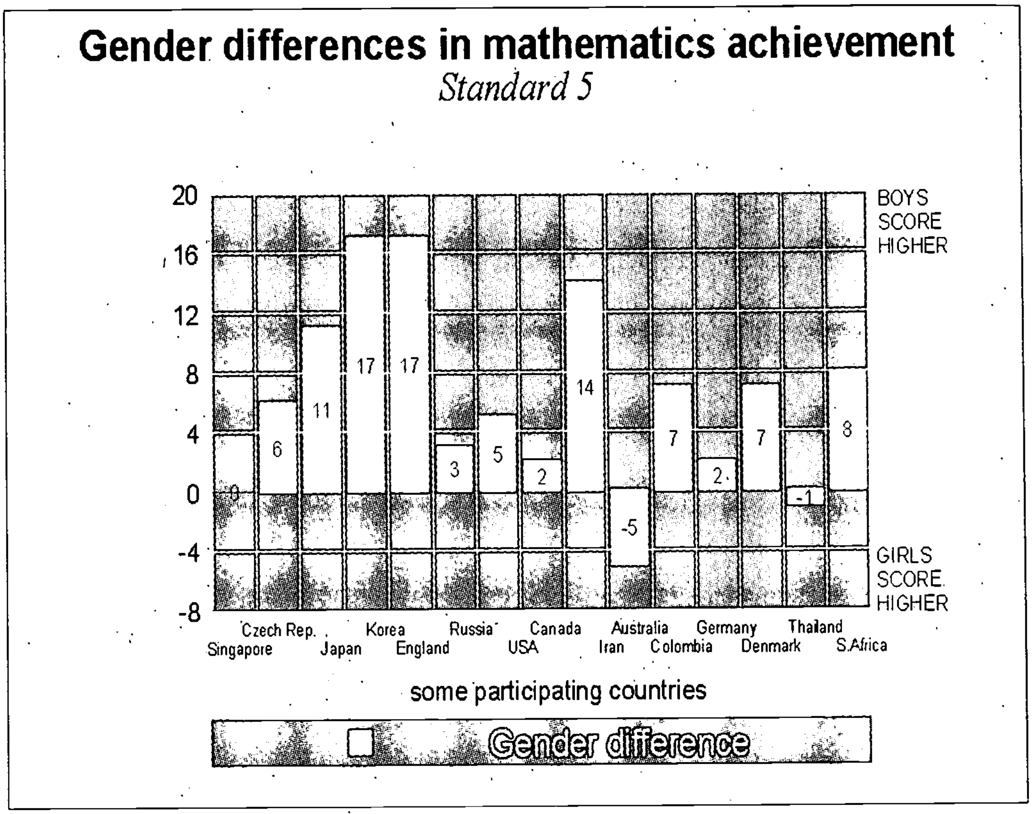
3.3 Gender differences in achievement in mathematics

Figure 3.4 Gender differences in mathematics achievement in Std 6



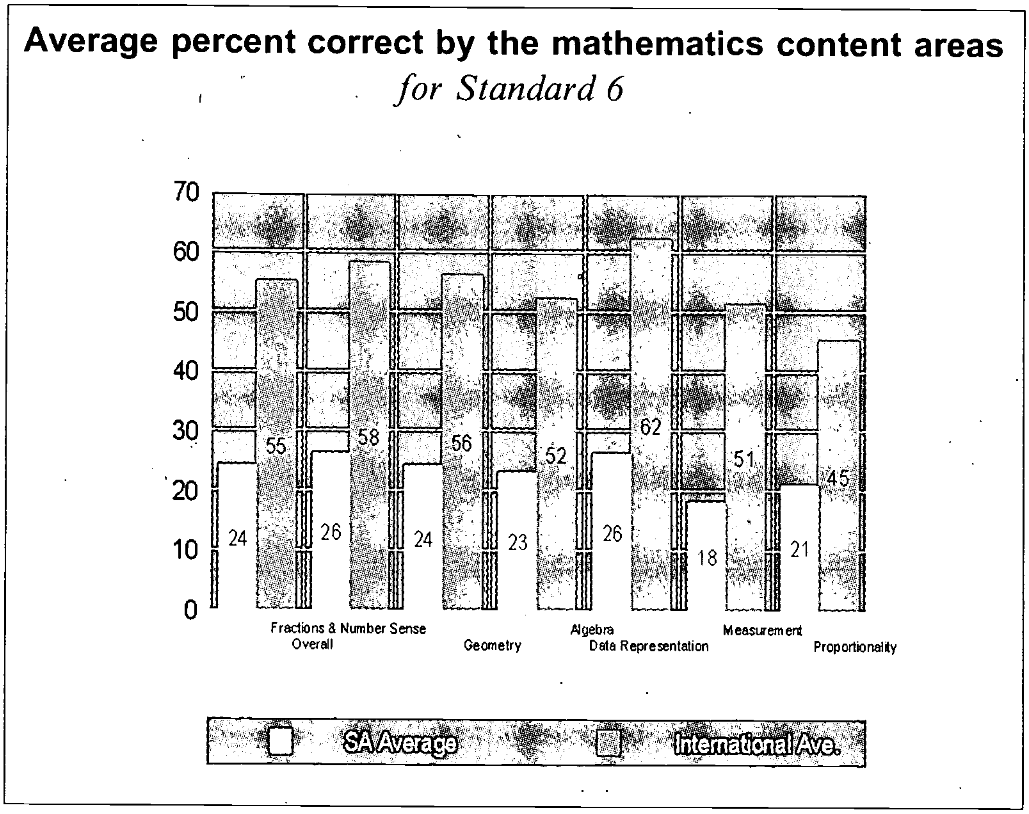
Figures 3.4 and 3.5 show the score differences between boys and girls for some of the participating countries, including South Africa. In most cases the differences are small and not statistically significant. Positive differences indicate that the boys scored higher than girls and negative differences the reverse (Beaton *et al.*, 1996a).

Figure 3.5 Gender differences in mathematics achievement in Std 5



3.4 Variations in achievement across the mathematics content areas

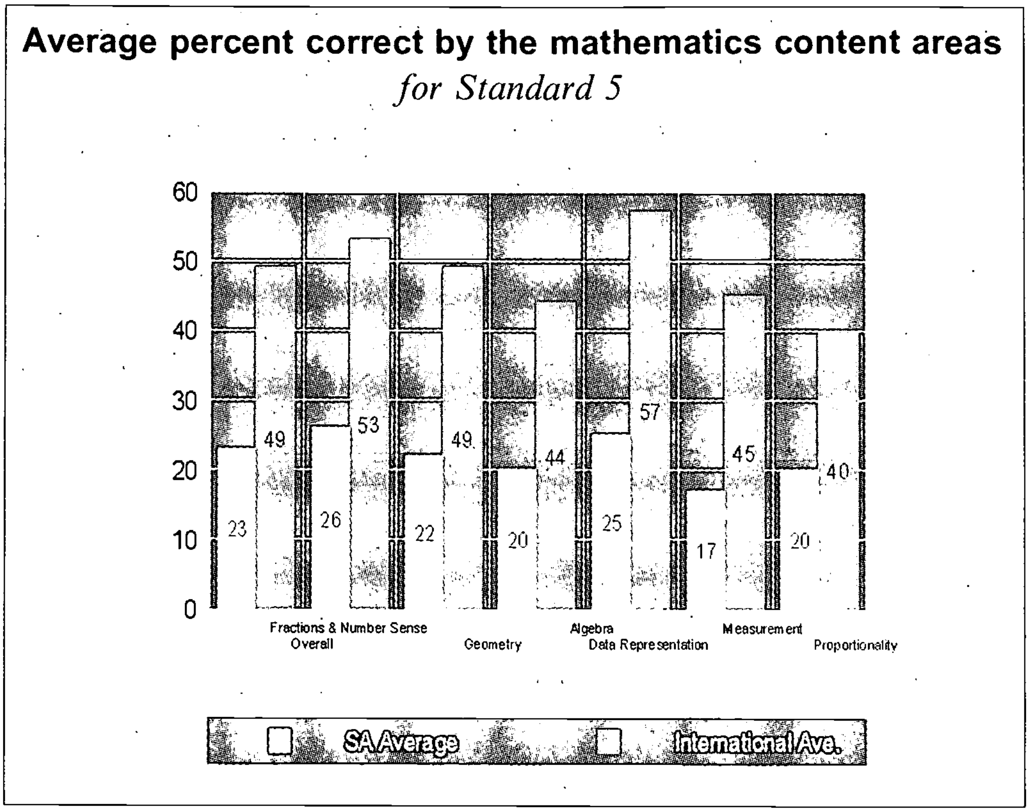
Figure 3.6 Average percentage correct by mathematics content areas Std 6



The six content areas covered by TIMSS in the study are fractions and number sense; geometry; algebra; data representation, analysis and probability; and proportionality. Figures 3.6 and 3.7 illustrate the average of correct responses in the different content areas for Std 6 and Std 5 respectively (Beaton *et al.*, 1996a).

The results reveal that countries that did well on the mathematics test overall, did well in each of the content areas. The international averages show that different content areas in TIMSS were not equally difficult for the students taking the test. Data representation, analysis and probability were the least difficult areas for both grades, whereas proportionality was the most difficult.

Figure 3.7 Average percentage correct by mathematics content areas for Std 5



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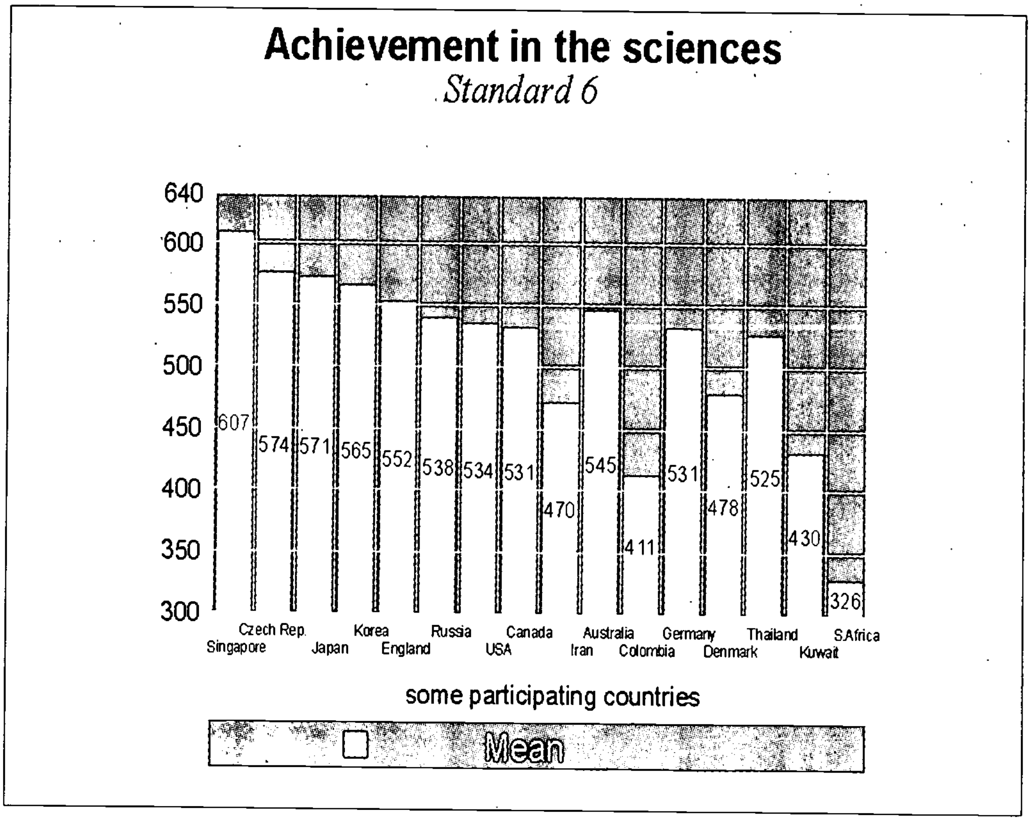
4 International comparison of the achievement of South African students in science

This part of the summary report illustrates the South African students' performance in the written science achievement test.

4.1 Overall performance in science in Std 6 and Std 5

Figure 4.1 Distributions of achievement in the sciences for Std 6

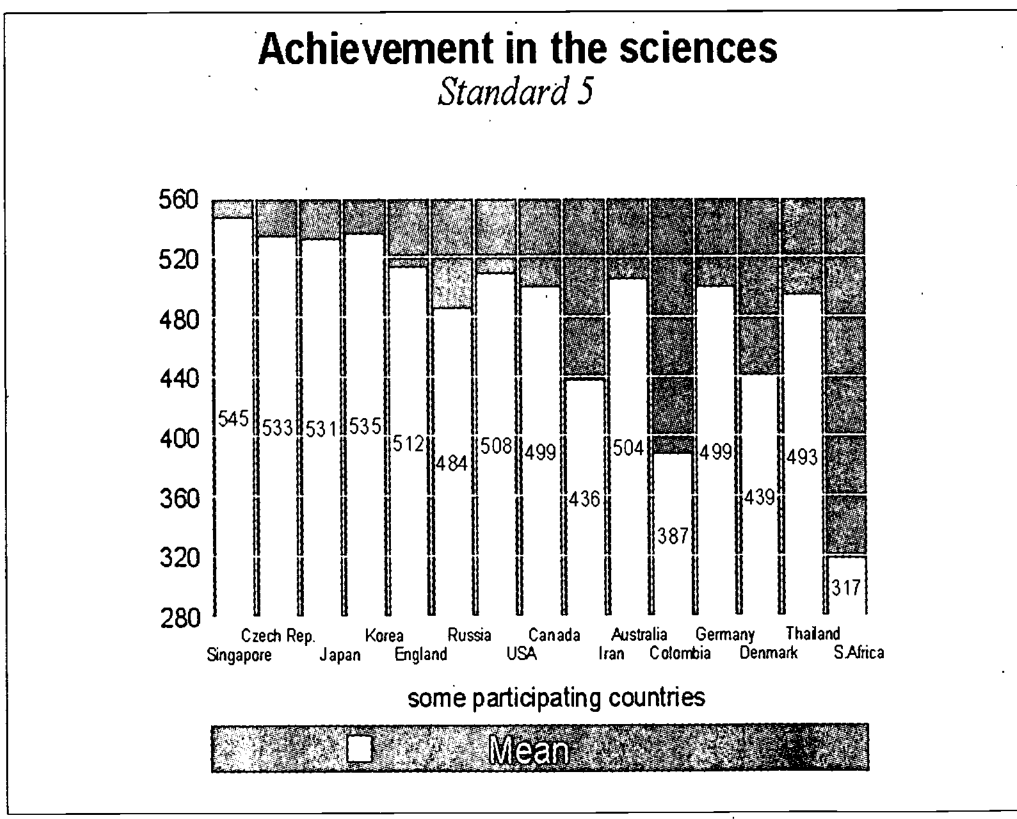


Figures 4.1 and 4.2 present the mean achievement for 41 countries at the Std 6 and Std 5 levels respectively. The score on the scale used by TIMSS is a score computed using the Item Response Theory, based on weighting factors determined by the relative

difficulty of questions. The scaling also allows the students' performance to be summarised on a common scale even though individual students responded to different questions in the test according to the rotation design of the test administration (Robitaille, *et al.*, 1996).

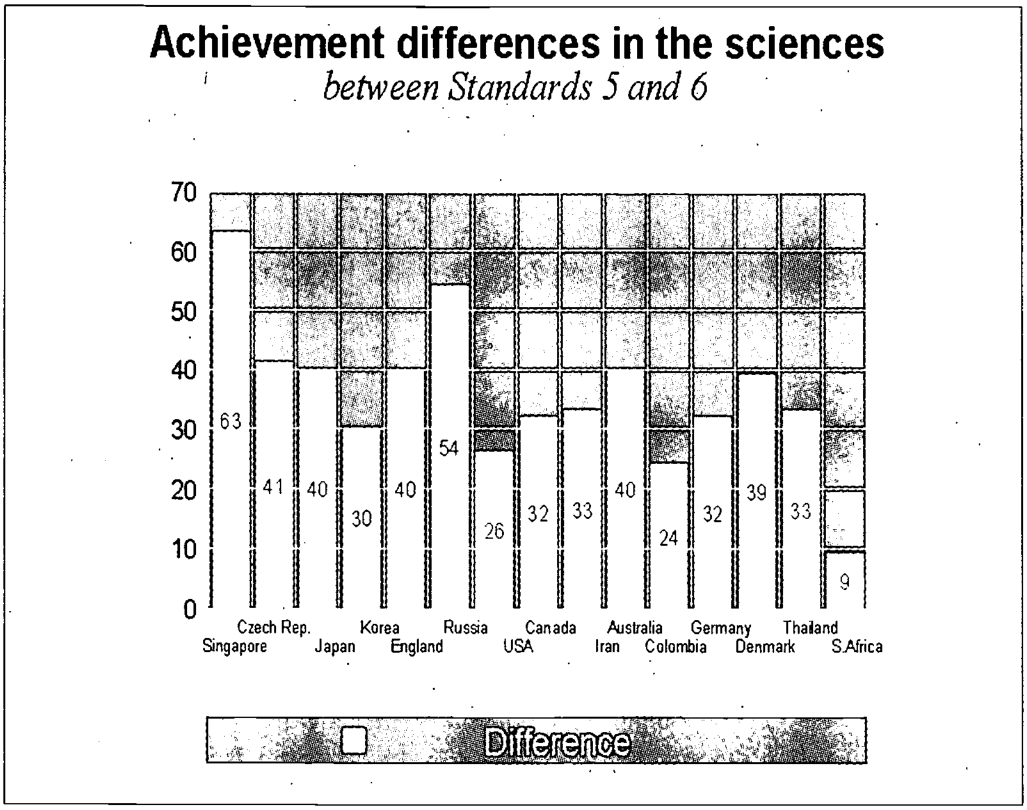
As is evident from both figures, there are substantial differences in science achievement across and within countries. The South African performance, in comparison to the other participating countries, can be described as very poor. South Africa lies well beneath the international mean (Beaton *et al.*, 1996b). However, South Africa's participation was significant as it was the only country on the continent of Africa to participate.

Figure 4.2 Distributions of achievement in the sciences for Std 5



4.2 Achievement differences in the sciences between Std 6 and Std 5

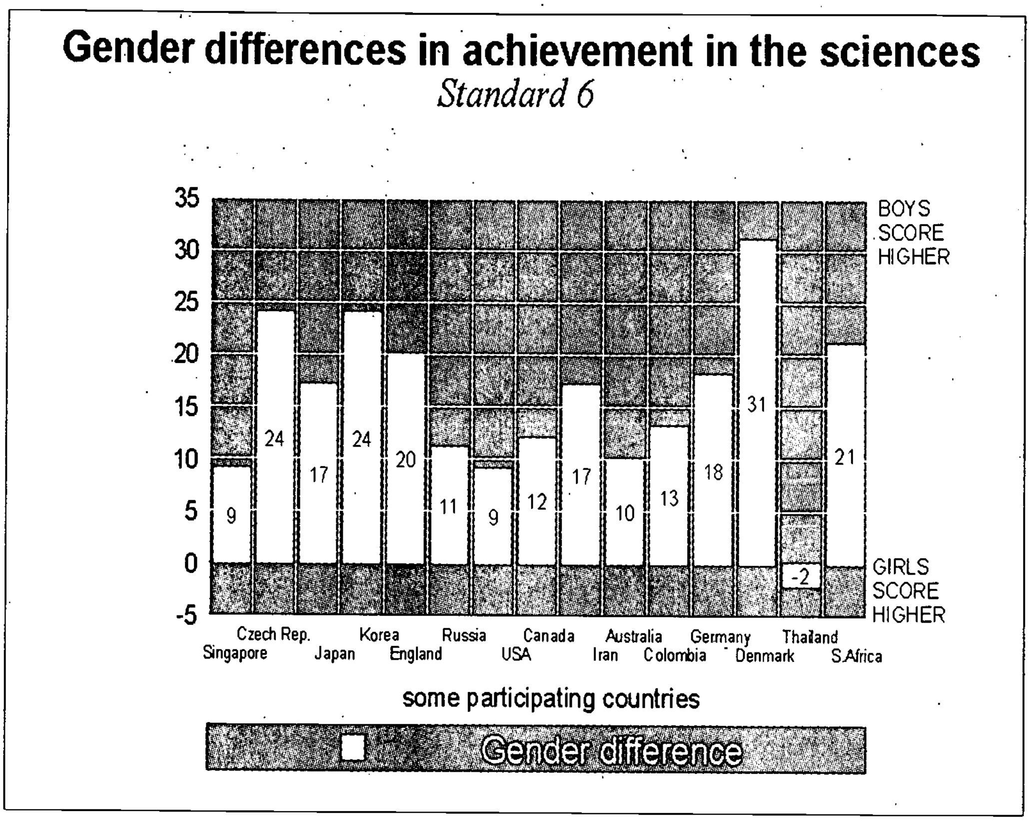
Figure 4.3 Achievement differences in the sciences between Std 6 and Std 5



Unlike most other countries participating in the study, South Africa's performance reflected very little difference between the performances of the Std 5 and Std 6 students. In fact, the difference in the achievement between the two standards is the smallest of all the countries, with a difference of only 9 points (Beaton *et al.*, 1996b). A number of factors could have influenced this result. Further analyses will be presented in a future report, a part of which will be devoted to exploring the possible reasons for and implications of these results.

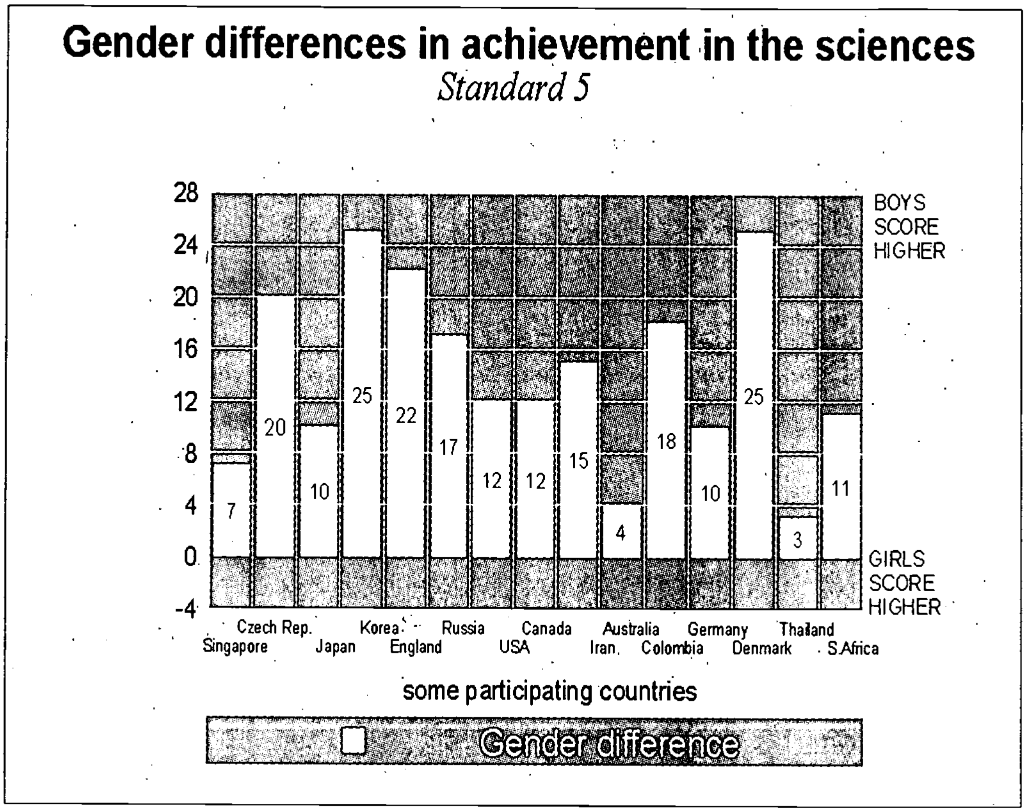
4.3 Gender differences in achievement in science

Figure 4.4 Gender differences in achievement in science in Std 6



In all countries except Cyprus and Thailand, the boys had a higher science score than the girls. However, the differences were often not statistically significant. Results for selected countries, including South Africa, are shown in Figures 4.4 and 4.5.

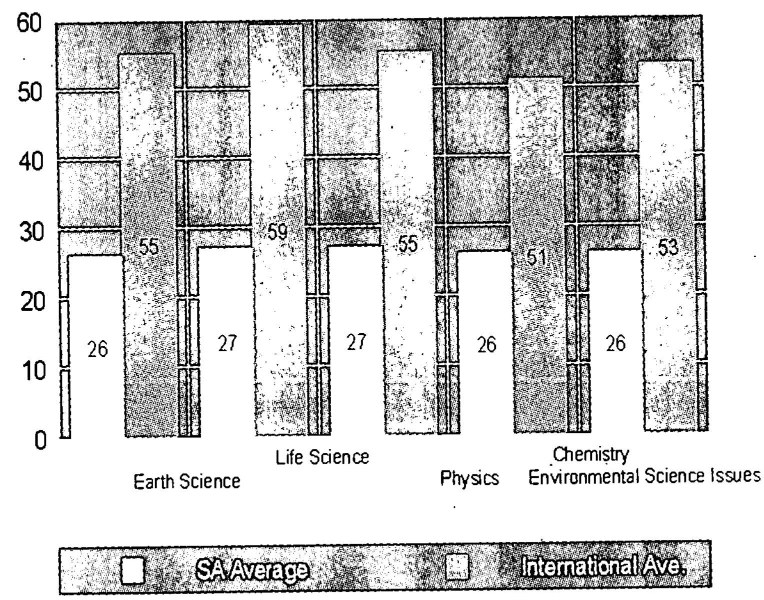
Figure 4.5 Gender differences in achievement in science in Std 5



4.4 Variations in achievement across the science content areas

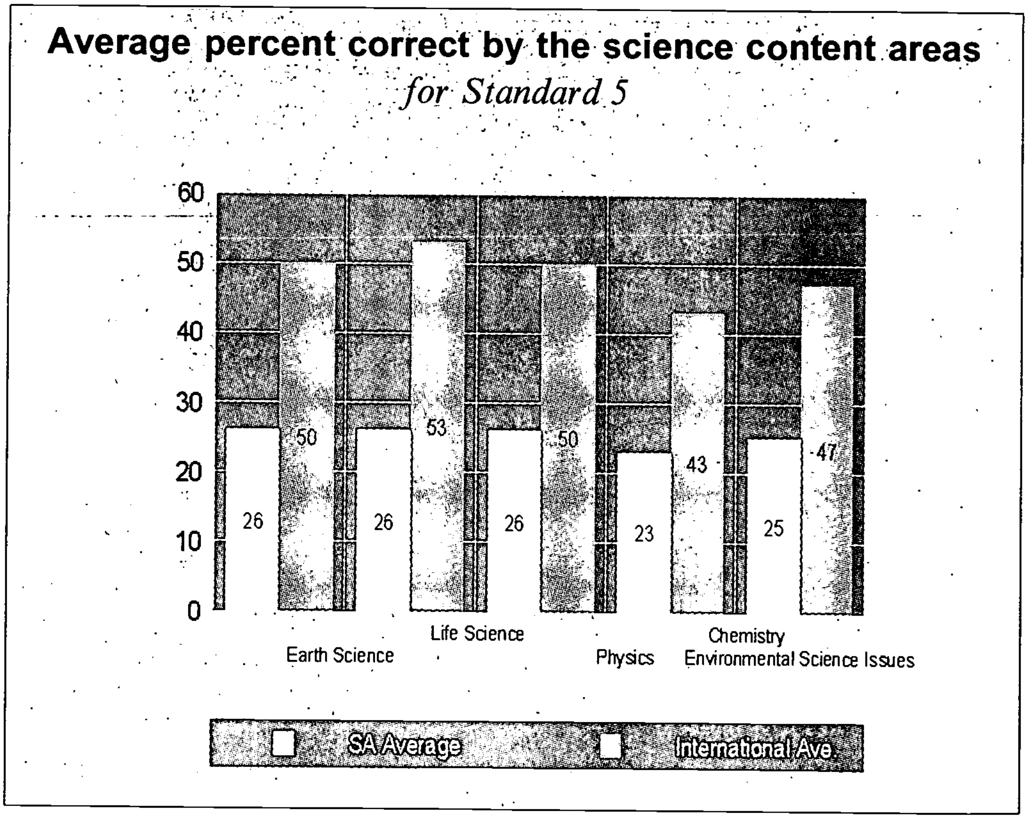
Figure 4.6 Average percentage correct by the science content areas for Std 6

Average percent correct by the science content areas
for Standard 6



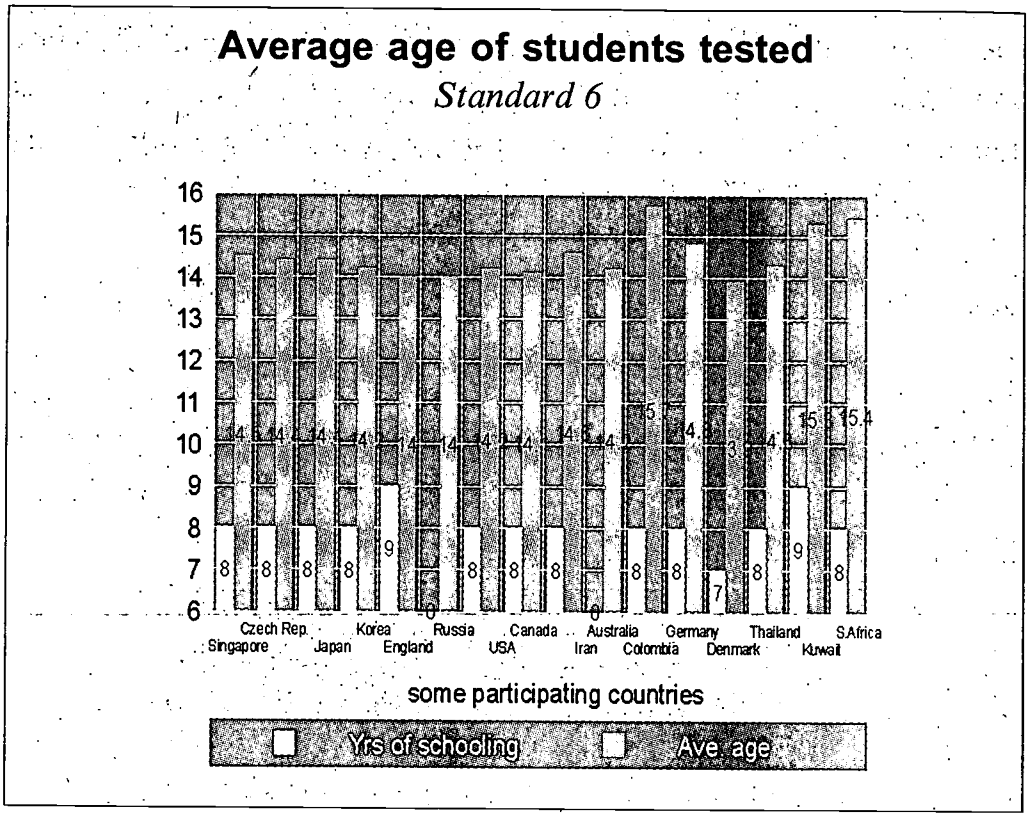
An examination of the performance of each country across the five major content areas: earth science, life science, physics, chemistry, environmental science issues and the nature of science, shows that countries that did well in the test overall generally did well in every content area; and those that did badly overall also tended to do badly in each of the content areas (Beaton *et al.*, 1996b). Furthermore, the international averages for the different content areas (the average percentages correct for questions in each of the content areas) indicate that the different content areas in the TIMSS test were not equally difficult for the students writing the test. The life science content area was the least difficult for both the Std 5 and Std 6 students internationally. The South African students results, although poor, did not reflect any significant differences in the results across the content areas or between the standards. They were fairly uniform throughout, with the possible exception of chemistry in Std 5 where, as in most countries, they tended to be low (Figure 4.7).

Figure 4.7 Average percentage correct by the science content areas for Std 5



5 Preliminary student biographical information

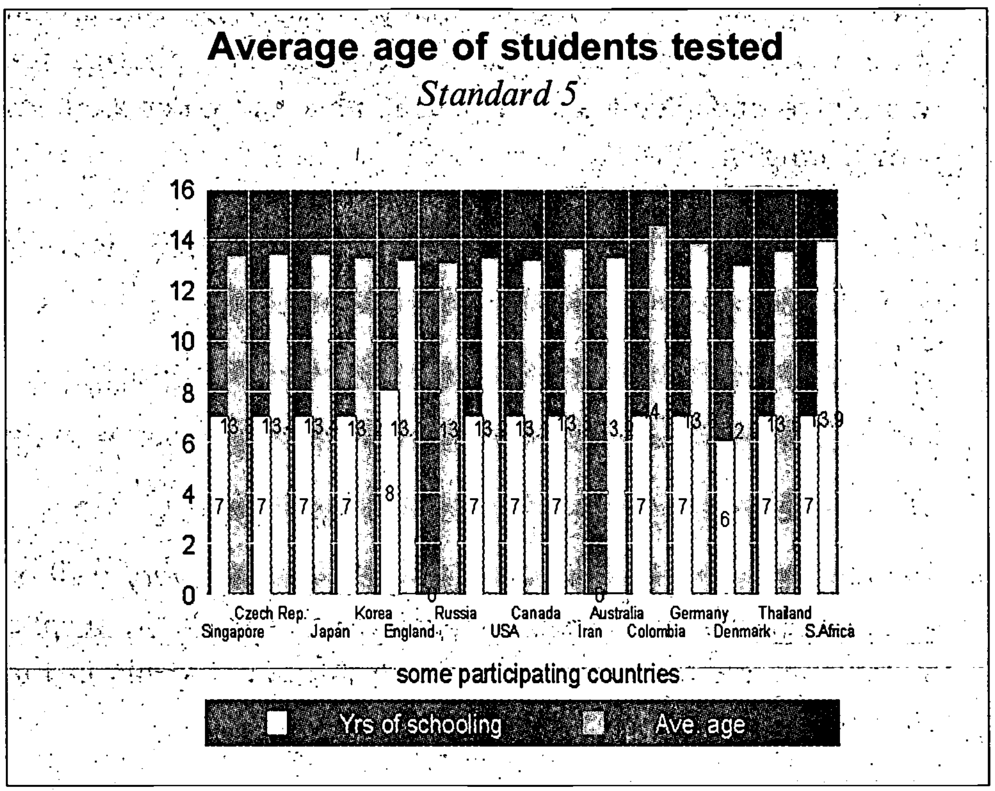
Figure 5.1 Students' age and years of schooling for Std 6



Figures 5.1 and 5.2 indicate the average age of the students participating in TIMSS and the years of schooling they had received by the time they reached Std 6 and Std 5 respectively. In both years, it is obvious that the South African students were above the average age, and were second only to Colombia in age. However, in respect of the years of schooling the South African situation compared well with the international scenario. As can be seen in both figures, South African students received the same

number of years of schooling as these in the majority of countries reflected in the figures.

Figure 5.2 Students' age and years of schooling for Std 5



An initial study by the HSRC of the student questionnaires has revealed the following highlights:

- Twenty-one percent of the students wrote the achievement tests in their home language.

- The amount of homework reported by the students for both science and mathematics was much lower than the international average for Population 2.

- Surprisingly, the amount of time spent weekly on extra lessons in science and mathematics was not very much less than that spent on homework.

- The average age of SA students in Std 5 was 13,9 years and in Std 6 was 15,4 years. The South African students' average age was the second oldest and only Colombia had older students participating in TIMSS.

- The average number of books reported in the home was far fewer than the international average.

- The number of students who reported that they had their own bedroom in the home was 56 to 59 %, which is surprisingly high in the South African context.

- The percentage of students who felt that they did very well or well in science or mathematics ranged from 74 to 80 %, in spite of the poor performance of the South African students in the achievement tests.

- The percentage of students who felt they needed to do a lot of hard work and studying at home in order to do well in science or mathematics was lower than that in nearly all the other countries. On the other hand, the percentage of students who felt that good luck was needed in order to do well was higher than that in nearly all the other countries. This was in striking contrast to the results from high- performance countries such as Singapore, Hong Kong, Korea and Japan, where very high percentages of students felt that hard work was important in order to do well.

- The percentage of students reporting that they liked science and mathematics ranged from 65 % to 74 %, which was similar to the percentages in other countries.
- There was a contradiction in the percentages of students who reported that they enjoyed learning science or mathematics, and those who reported that they found the subject boring. For example, 84 % of Std 5 students said they enjoyed learning science, and 39 % found it boring.
- The figures for career choices in the natural sciences are disturbing. In the case of Std 6 students, if students were to choose a career in the natural sciences, 32 % would choose biology, 24 % would choose physics and only 7 % would choose chemistry.

6 Possible factors affecting the performance of South African students

This chapter examines possible reasons for the poor performance of South African students in the Population 2 achievement test, and for other findings in TIMSS.

In this initial summary report, it would not be appropriate to comment on these reasons in detail, since much of the analysis is not yet complete. A list giving possible reasons for the findings, and in some cases preliminary comments concerning their relevance, has been compiled below.

A number of publications in recent years have examined the deficiencies of South Africa's school education system, especially where previously disadvantaged communities are concerned. These publications either discuss education in general, or mathematics and science education specifically. (See, for example, the White Paper on Education and Training (1995), Kahn 1993, Essop 1992 and CEPD 1994). The problems highlighted by these publications can be summarised as follows. Some or all of the problems can be associated with South Africa's TIMSS performance.

6.1 Problems in the South African school education system

6.1.1 Home environment

Many students come from socioeconomic backgrounds which are so poor that they can scarcely be imagined by first-world researchers. Survival is often given priority over education. The generation presently at school often have parents who themselves have at best a basic primary education, and are therefore unable to assist with school work. This provides a very poor incentive to study at home, even when this is physically possible. Another factor arising from this kind of environment is malnutrition, which can have adverse effects on powers of concentration.

6.1.2 General school environment

A great many schools have inadequate buildings, poor or non-existent libraries, laboratories and other facilities, overcrowded classrooms, textbook shortages, lack of teacher support mechanisms and weak school leadership. Physical and other forms of isolation, leading to poor communication with the outside world, often cause serious problems (CEPD 1994).

In addition, many schools have suffered disruption in recent years, through boycotts, strikes, stayaways, etc.. Even when overt disruption does not occur, problems arise from irregular attendance by both students and teachers. The causes of this disruption and malaise can be traced back to the time when many schools were in the forefront of the liberation struggle. Now that political liberation has been achieved, the culture of learning still has to be normalised (Essop 1992).

6.1.3 Quality of teachers and teaching

There is a severe shortage of properly qualified mathematics and science teachers at the secondary level. Unfortunately this shortage has been masked recently by the well-publicised surplus of teachers in other areas of education. The problem is exacerbated by the fact that many trainee mathematics and science teachers at teacher training colleges have chosen the course very much as a second or third choice, having failed to be selected for their first choice of career. Consequently, many of these students are not strongly motivated to become mathematics or science teachers (Howie and Wedepohl 1993).

Inadequate subject knowledge and poor motivation lead to a lack of confidence and inspiration in the classroom, which has a negative effect on the learning process. The teachers are then poor role models for students, which means that few of these students will wish to become teachers themselves one day.

6.1.4 Peer environment

The peer environment in many schools is not supportive of those students who do wish to do well academically. In an era where equality of opportunity sometimes leads to an expectation of equality of outcomes, students can feel uncomfortable if their achievement is notably better than the average.

6.1.5 Gender factors

As in many other countries, there are subtle and not-so-subtle discouragements for girls who have an inclination to enter mathematics-based or science-based careers. Apart from the discouragements they sometimes experience from teachers, the burden of household work often falls on the girls in the home, which has a negative influence on study time (see, for example, Ngwema, 1996).

6.1.6 Homework

There are indications that South African Population 2 students do considerably less homework than the international average (see 5 above). An improvement in teacher quality and motivation could improve this situation, as could a recognition of the important contribution that homework makes to learning.

6.1.7 Language of instruction

For many students (especially African students) the language of instruction in Standards 5 and 6 is not the same as their home language. This often leads to communication problems, particularly where unfamiliar new concepts in science and mathematics are involved. For this reason it is also important to phrase test questions in language that is as clear and direct as possible.

6.1.8 Curricula

A number of criticisms have been levelled at South African mathematics and science curricula over the years. Some of these criticisms are:

- Syllabi used are outdated, irrelevant and boring
- The general approach is "chalk and talk" rather than "hands-on"
- Assessment methods are inappropriate

In an attempt to deal with these problems, a major curriculum reform initiative is currently under way in South Africa.

6.1.9 Student motivation

Largely as a result of the above factors, the motivation of students to do well in mathematics and science tends to be low. Motivation is also adversely affected by the fact that mathematics and science are widely considered to be "difficult" subjects by students. Also, for 40 years there has been little encouragement for African students to study mathematics and science.

As mentioned in Chapter 5, South African Population 2 students are much more inclined to see luck as being necessary for success in mathematics and science, and much less inclined to attribute success to hard work. Fortunately, there are signs from a recent unpublished study (Howie 1997) that these trends are being reversed in the case of older students of science and mathematics.

A recent book (Drew, 1996) indicates that minority students in the USA are showing considerably improved motivation and achievement in mathematics when it is put to them that they are **expected** to achieve, rather than emphasising the "remedial" nature of special programmes designed for minority students. The same book reveals that there is considerable improvement in the achievement of minority students who actively study in groups, rather than study on their own. Perhaps these are lessons from which South Africa can learn.

6.2 Preliminary comments on the relation of the above problems to the TIMSS findings for South Africa

It should be emphasised that these comments are preliminary, since the analysis in many cases is not yet complete.

The most striking feature of the TIMSS results from South Africa's point of view, was that the overall results were very poor. Although the various bodies associated with TIMSS have often emphasised that the project should not be seen as a "horse race" between countries, the overall level of South Africa's achievement gives grounds for concern. It can be said with some confidence that all of the nine problems listed in 6.1 contributed to some extent to the poor results. However, a careful analysis of the TIMSS results and questionnaires should help to identify the most important reasons, and especially to identify those factors that something can be done about.

6.2.1 General school environment and the quality of teachers and teaching

The general school environment and the quality of teachers and teaching, taken together, must have been a major factor in the poor results. Even a cursory inspection of the results shows that schools in relatively affluent areas, and with good facilities, produced higher scores on average.

An interesting phenomenon has been associated with senior certificate results (Std 10) in recent years. The overall results in disadvantaged communities have not been good, yet a few individual schools in these communities have achieved much higher pass rates than the average, in spite of the schools concerned having poor facilities. The evidence is strong that in these schools the ethos among students, staff and parents is achievement oriented, and that absenteeism rates for pupils and teachers are low. The commitment of the teaching staff also seems to be high.

An attempt will be made to see if any of the variability in TIMSS Population 2 results is due to this kind of effect.

6.2.2 Class size

An interesting finding internationally is that class size does not necessarily correlate inversely with performance in the achievement test. Some of the best-achieving countries had relatively large classes.

However, there could be other factors in the culture of these countries that permit large class size without adversely affecting performance. These factors are not necessarily present in South Africa, so that one should be careful about simplistically attempting to transfer the practice in these countries to South Africa.

6.2.3 Influence of the curriculum on the results

An interesting finding from the international study was that, for nearly all countries, achievement in mathematics and science did not significantly depend on whether test questions were covered by the intended curriculum or not. A typical case was that of Korea, one of the top-performing countries. Only 29 % of the grade 7 science items were covered by the intended curriculum for Korea. However, while Korean students averaged 64 % correct on these covered items, they averaged only three percentage points less (61 %) on all the items in the test, including those not covered by the intended curriculum. This finding also applied to the South African results. Does this imply that access to material outside the curriculum has a major influence on achievement? Or that students who do well on questions covered by the intended curriculum can make an informed guess about the answers to questions which are not covered by the curriculum? These and other possible reasons for the finding will be analysed further — almost certainly in other countries too.

6.2.4 Language

All students wrote the achievement test in the language in which they received formal instruction. However, for a large majority of students this was different from the home language. This must have put the students at a disadvantage, but to what extent? An attempt will be made to extract some information concerning this point.

6.2.5 Additional comments

Other points of interest are the following:

- In spite of the points made concerning **gender discrimination** in 3.1, the score difference between girls and boys was small in South Africa. This is one of the positive factors to come out of the study. However, why is this? Knowing why could provide some positive feedback to teachers.
- The **improvement from Std 5 to Std 6** is smaller for South Africa than for all the other countries. It is almost certainly too simplistic to blame this solely on inadequate teaching at the junior high school level. The reasons for this finding will be analysed in some detail.
- When attempting to improve mathematics and science education in South Africa there will be **no single, magical cure-all solution**. The most successful strategy will consist of simultaneous attacks on a number of different fronts, i.e. an "and...and" approach rather than and "or...or" approach. One can at least draw considerable encouragement from the fact that some countries have experienced significant improvements in achievement between the Second Mathematics and Science Studies and TIMSS. Reasons for this improvement over time will be analysed, so as to provide lessons from which South Africa can learn.

7 Conclusion

This summary report has only scratched the surface of the preliminary analysis of South Africa's participation in TIMSS. The second and third reports in the series of the TIMSS reports on the Std 5 and Std 6 results should assist in providing explanations for the findings.

The overall Std 5 and Std 6 results of TIMSS paint a bleak picture of science and mathematics education in South Africa. However the data that produced these results also contains some possible answers and solutions. The benefits of participating in a study such as TIMSS are incalculable financially. South Africa will the benefits of such rich baseline data for some time to come.

TIMSS has provided the country with valuable information that will enable policy makers to ascertain quantitatively and relatively objectively, for the first time, the status quo in science and mathematics education in South Africa. The study is intended to be longitudinal, and the HSRC believes that great advantages will be obtained by monitoring the progress of the various programmes and newly introduced reforms to the education system. If this study is undertaken every two years over a period of say twenty years, a valuable assessment of the progress of the government's initiatives can be made.

If South Africa is to succeed as a country in a rapidly changing competitive world where science, engineering and technology are becoming increasingly important, and if it is to develop and prosper economically, then a premium must be placed on science and technology education. The production of human resources in these fields has become of primary importance. As the position stands now, South Africa faces the prospect of losing the battle to produce this manpower. However, when programmes, changes, initiatives and reforms are implemented in science and mathematics education in the future, there will at least be a monitoring system, based on TIMSS, that one can use to evaluate their impact.

SJH
19 February 1997

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