DOCUMENT RESUME

ED 422 174 SE 061 710

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TITLE	Mathematics and Science Literacy of Final-Year School Students in South Africa. A Report on the Performance of South African Students in the Third International Mathematics and Science Study (TIMSS).
INSTITUTION	Human Sciences Research Council, Pretoria (South Africa).
PUB DATE	1998-02-00
NOTE	76p.
AVAILABLE FROM	Human Sciences Research Council, 134 Pretorius Street, Private Bag X41, Pretoria, South Africa 0001.
PUB TYPE	Reports - Research (143)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Academic Achievement; Foreign Countries; *High School Students; High Schools; *Mathematics Education; *Science Education; Tests
IDENTIFIERS	*South Africa; *Third International Mathematics and Science Study

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 students in 41 countries being tested in mathematics and science at five different 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 of the mathematics and science literacy testing of final-year school students in South Africa. The results of those students who participated in TIMSS in their final year of schooling and student background are discussed in detail. (Contains 15 references.) (ASK)

MATHEMATICS AND SCIENCE LITERACY OF FINAL-YEAR SCHOOL STUDENTS IN SOUTH AFRICA

TIMSS SOUTH AFRICA

SJ Howie
CA Hughes

TIMSS-SA

MATHEMATICS AND SCIENCE LITERACY OF FINAL-YEAR SCHOOL STUDENTS IN SOUTH AFRICA

A report on the performance of South African students in the Third International Mathematics and Science Study (TIMSS)

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February 1998
Human Sciences Research Council
Pretoria

Design and layout: Susan Smith
Cover design Alta Benadie
Cover illustration: Artist L.P. Maraloki

Published by:
The Human Sciences Research Council (HSRC)
134 Pretorius Street
Pretoria

President:
R.H. Stumpf

Group: Education
Executive Director: S.W.H. Engelbrecht
Printed and bound by Sigma Press, Pretoria

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PREFACE

In most countries of the world, education and training are important national issues. Cross-nationally there is a continuous interest in and effort to improve educational quality. This endeavour to improve is directly related to the view that there is a positive relationship between the quality of the education and training provided in a country and the ability of that country to perform economically in the global context.

There is also a growing consensus that achievement in mathematics and science subjects is symptomatic of the quality of education and training in a country and a good yardstick of a country's potential to be economically competitive. The IEA's mathematics and science surveys have over the years created an instrument which can be used by participating countries to measure where they are and what they need to do in order to improve the quality of their mathematics and science education.

South Africa joined the IEA in 1993 and opted to participate in the Third International Mathematics and Science Survey (TIMSS). Even though TIMSS at that stage was already well under way, participation was considered to be of such importance that additional steps were taken to catch up in order to share in the results and benefits of the project. This report discusses the results of the Population 3 survey group, in other words, the final year school students, and therefore represents the last group of respondents to the TIMSS questionnaires and achievement tests.

The importance of the TIMSS results is that they provide South Africa with a picture of how students achieve in mathematics and science education, and some information about environmental issues which may impact on this achievement. The TIMSS results can be used to evaluate South Africa's position relative to that of other countries and whatever the shortcomings may be of such a comparison, it does provide a rough estimate of the level of achievement and the possible shortcomings of the educational system. Deeper analysis of the data could also assist in identifying some of the most important factors contributing to the level of achievement.

In the past, in many of the participating countries, the results of IEA investigations lead to renewed policy analysis and development. In South Africa the challenge is to respond effectively to the TIMSS results. Factors contributing to the poor results have to be carefully analysed and as a matter of urgency, remedial actions need to be taken. Given the fact that the poor results are probably due to a multitude of factors which financially and logistically cannot be tackled simultaneously, care will have to be taken in deciding what to concentrate on first. It would also be unwise to set unrealistic objectives. We can only hope to make moderate improvements in the next five to ten years. The important point though, is to determine what is viable to achieve and then to go all out for the set objectives.

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Acknowledgements

- The authors are grateful to the following people:
- The teachers, principals and the students at the sampled schools, without whom the study would not have been possible.
- Dr Gray and Dr Drost who were formerly part of the TIMSS research team, and who contributed significantly to the operationalisation and management of TIMSS.
- Dr Engelbrecht, executive director of Group: Education, and Dr Kraak, director of the Unit for Education and Training Systemic Studies, who made valuable contributions to the compilation of this report.
- The education departments and their officials, especially the provincial co-ordinators who did a sterling job in difficult circumstances.
- The curriculum analysis team who most willingly completed an enormous task, 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 HSRC Group: Education, Computer Centre, and the data-capturing staff, who assisted in times of crisis and who made our participation possible.
- Elsie Venter who has been invaluable with all our data analysis.
- Palesa Moalosi who carried the administration load.
- All the students who organised the test instruments in the data store.
- The contract workers who did the coding of all the papers and the data capturing.
- Those involved in the sampling of the schools for the study, especially Dr Claassen (previously from Group: Education).
- The HSRC Management for its guidance and assistance throughout the TIMSS project, in particular Dr Stumpf (President of the HSRC), Dr Engelbrecht, Mr Van den Berg, Dr Nieuwenhuis and Dr Kraak.
- Dr Fred Shaw, the quality control monitor, for his contribution and guidance.
- Professor T. Plomp (Chairman of the International Association for the Evaluation of Educational Achievement) for his support and advice.
- Last, but not least, the International TIMSS centres in Boston, Vancouver, Ottawa, Hamburg and Melbourne for their assistance, guidance and leadership.

Executive Summary

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 means 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 41 countries being tested in mathematics and science at five different year levels (equivalent to Grades 4, 5, 7, 8 and 12 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. 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 was selected from each country. The way in which the procedures were implemented was monitored. The International Association for the Evaluation of Educational Achievement (IEA), based in the Netherlands, was responsible for undertaking TIMSS and other earlier international comparative studies.

Major research questions guiding TIMSS

The development of 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?

Students participating in TIMSS

The TIMSS study investigated mathematics and science achievement at different stages of schooling and defined the following three target populations:

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. Grade 7 and Grade 8 classes were tested together as one group (as Population 2) and the Grade 12 classes were tested as Population 3. The Human Sciences Research Council conducted the survey in South Africa.

This report is the first of a series that will provide information on the performance of the Grade 12 students in 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 pilot studies and field trials. The questions were also reviewed by experts both 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.

Comparative studies in education gain more meaning when considered in relation to the educational context in which they are done. In TIMSS, data on a considerable number of contextual factors included in various questionnaires were collected from principals, teachers, students, 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 the decision was made to test Grade 7, 8 and 12 students only, and not to test population 1 (grade 4 and 5 pupils) owing to financial constraints and the issue of the medium of instruction in the primary schools for this age group. A randomly selected national sample of schools, representative of all provinces, race groups, urban and rural communities, was identified.

During 1995, grade 12 students were tested in about 150 classes and wrote a general paper containing mathematics and science questions. Data from 2 757 of these students were included for analysis in the study. The students also completed the same background questionnaires. Different questionnaires, which contained questions about socio-economic and demographic conditions that could have an impact on the teaching and learning of mathematics and science, were administered to school principals.

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.

Twenty-two countries, including South Africa took part in the study of final-year students in TIMSS. A number of factors were revealed when these countries were compared:

- There was a great variety in the nature of the upper-secondary education systems of the countries participating in Population 3.

- South Africa's TIMSS coverage index[1] was one of the lowest.
- South Africa had the lowest proportion of people living in urban areas.
- South Africa had the second highest public expenditure (as a percentage of the gross national product) on education.

These systemic and demographic factors must be considered when comparing countries and their education systems, particularly when performance results are interpreted.

Highlights of results for Grade 12

These highlights reflect the results of the achievement tests taken from the international report on TIMSS (Mullis, *et al.* 1998), the HSRC database and some preliminary findings drawn from the questionnaires. In-depth analyses and detailed findings regarding the Grade 12 students' results will be released later.

Achievement tests

- The overall scores of South African students were significantly lower than those of students in other countries, suggesting that South African final-year students have a low level of general numeracy and scientific understanding and skills. This was ascertained by students' responses to test items focusing on problems applied to the real world.
- South Africa's results did not display any areas in science and mathematics in which students performed well. In many of the individual test items, South Africa performed the worst. South African students appear to have difficulty with problems that involve graphic interpretation. The more difficult multiple-choice questions, as well as free- response items, were handled poorly. It would appear that South Africa students generally struggle with constructing their own answers, since they performed very poorly on items when responses had to be creatively generated.
- There was evidence of language difficulties among the students in the international study, including the South African students. The majority of the South African students wrote the TIMSS tests in a language that was not their mother tongue. Since the literacy test paper comprised largely word problems, it is possible that the language factor had a negative impact on achievement.
- South African students with English and Afrikaans as a home language performed significantly better than those students with other home languages.
- South Africa was the only country with no significant difference in the performance of boys and girls in either mathematics or science. In numerous other countries, boys performed better than girls.
- Free State, Gauteng and KwaZulu-Natal performed consistently better than the other provinces. Students in these provinces performed above the national average for mathematics and science.

1 The TIMSS coverage index was calculated for each country and was "an estimate of the percentage of the school-learning age cohort covered by theTIMSS final year students sample" (Mullis, *et al.* 1998:17).

- South African students performed marginally better in mathematics than they did in science.

Preliminary findings from the student questionnaires

An initial examination by the HSRC of the student questionnaires revealed the following:

- A large proportion of South African students wrote the literacy test in their second or third language.
- The average age for South African Population 3 students was 20.1 years. Most of the sampled students in other countries were 17-19 years.
- A large majority (85 %) of students in SA were enrolled for biology. About 70 %[2] had included mathematics in their curriculum.
- Of the South African sample, 95 % had intentions of studying further, and of these, 75 % planned to go to university. The surprisingly high proportion wanting to go to university is probably related to the heavy emphasis on academic streams at school level in this country, and the perception that university degrees are prestigious and will enhance career advancement. The most popular area for further study for South African students was engineering, followed by business. That the highest proportion of students elected engineering as their intended area of study was surprising.
- South African students in general prefer school biology to physics and chemistry, and this seems to support their future study plans which place physics and chemistry at the bottom of the list.
- The greatest proportion of students in South Africa reported that the highest educational level attained by either parent was primary school, and then to a lesser extent, secondary school.
- South African students reported that their homes contained only a limited amount of books. Almost 60 % of students had fewer than 26 books in the home, whereas all the other countries had only 5–23 % of students reporting this few books at home.
- In South Africa 92 % of students indicated that they did not have a computer at home. Concerning the frequency of computer use at school, home or anywhere else, 81 % of South African students said that they rarely or never used a computer. In contrast, the highest proportion of students in countries such as Australia, Canada, the Netherlands, New Zealand, Switzerland and the USA reported that they used computers daily.[3] In the information-rich global society in which we live it appears that our final-year students have very limited exposure to computer technology in comparison to a number of other countries.

2 There may be overlap in the biology and mathematics groups

3 Students had to indicate whether they used computers *rarely* or *never*, *daily*, *weekly* or *monthly*.

- South African students reported spending 5 hours a day on homework – the most time compared to all other countries. Despite spending so much out of school time on academic work, this did not enhance their performance. Students in other countries spent considerably less time on homework and the highest achievement was associated with 1–3 hours of homework a day.

Many of these findings will be analysed in greater detail and these analyses will be published in forthcoming reports. This baseline data has 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 is significant and will provide much-needed information to meet the educational challenges that will face this country at the beginning of the twenty-first century.

Outline of the report

- Chapter 1 offers a description of the design and administration of TIMSS.
- Chapter 2 provides an overview of the mathematics and science literacy of the study.
- Chapter 3 discusses the findings of the students' contextual questionnaire.
- Chapter 4 describes the students' overall performance in the mathematics and science literacy test.
- Chapter 5 describes the students' performance in mathematics and science literacy individually.
- Chapter 6 discusses the students' performance on different mathematics and science literacy example items.
- The conclusion summarises the preliminary analysis of TIMSS.

Chapter 1

Introduction to TIMSS

Key Points

- TIMSS is the largest and most ambitious international study of mathematics and science achievement at school level ever undertaken.
- TIMSS was developed to assess the national curricula, the school and social environment, and achievement in mathematics and science of different systems of education.
- Three levels of curriculum were investigated: the intended, the implemented and the attained curriculum.
- Four main research questions were posed:
  - (1) What are students expected to learn?
  - (2) Who provides the instruction?
  - (3) How is the instruction organised?
  - (4) What have students learned?
- Achievement tests and questionnaires were administered. Sampling was strictly controlled internationally, was drawn randomly and was nationally representative

Chapter 1

Introduction to TIMSS

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. Worldwide more than half a million students in 41 countries participated in the project.

This report represents a summary of the international report on TIMSS, focusing on South Africa's participation and, in particular, the study of final-year students is discussed from a national and an international perspective. South Africa's results from another part of the study (results of the study on Grade 7 and Grade 8) can be found in the report entitled *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* (Howie, 1997). More information on the South African results can also be found in the international reports entitled *Mathematics achievement in the Middle School years: IEA's Third International Mathematics and Science Study* and *Science achievement in the Middle School years: IEA's Third International Mathematics and Science Study* (Beaton *et al*, 1996a) and *Science achievement in the Middle School years: IEA's Third International Mathematics and Science Study* and *Science achievement in the Middle School years: IEA's Third International Mathematics and Science Study* (Beaton *et al.*, 1996b).

This report will be followed by others that will investigate issues highlighted here 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. As students leave school and enter higher education and the workplace, the above skills, in addition to competence in mathematics and science, will be crucial.

With the need for populations to be better educated (in South Africa's case, the basic need for literacy and numeracy) in the climate of shrinking national budgets, countries around the world have been looking for methods of making teaching and learning more effective. International studies are a means of providing information on student achievement and the factors that play a role in such achievement. They "help to improve an understanding of educational systems. As there are no absolute standards in educational achievement, comparative studies are essential to provide policy makers and educators with information about the range of educational quality in relation to other national systems. Studies therefore contribute to setting realistic goals for education systems, as well as monitoring school quality'' (Plomp, 1992:278). Secondly, comparative studies may also be helpful in ''understanding the causes of observed differences in student performance, by exploring cross-nationally relations between school achievement and such factors as curricula, amount of time spent on school work, and teacher training, parental support and many other explanatory measures'' (Plomp, 1992:278). The challenge will always be to learn more about effective teaching and learning, both for educators and for policy makers in the education field.

In South Africa, poor matriculation results continue to dominate the news at the end of every school year. During 1995 and 1996 the best school attendance figures were witnessed in years, but poor results were still evident. The story was repeated in 1997 when less than half of the country's matriculants passed, despite changes and reforms in the Department of Education. The reasons for the failure are varied, and any reforms that are implemented 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 Evaluation 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 a deep 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. The project 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 do so.

TIMSS was developed to assess the national curricula, the school and social environment and achievements in science and mathematics in the participating countries. 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.

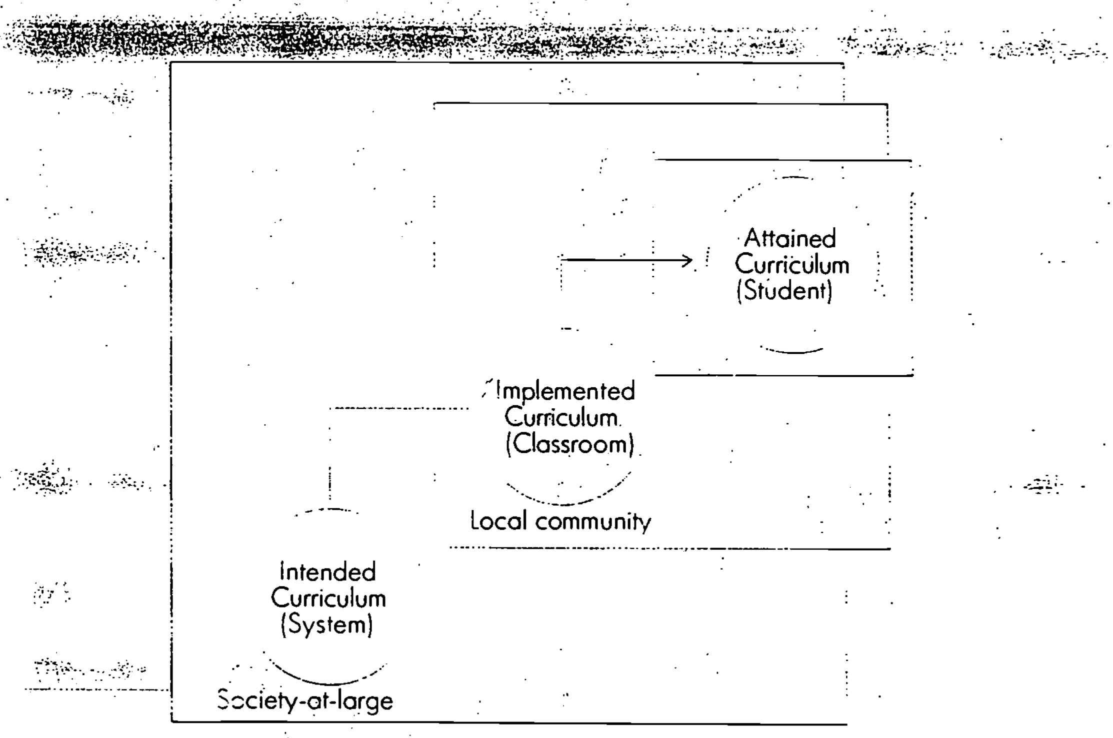
The first part of this report gives an overview of the entire project of TIMSS, including its conceptual framework, various components and the design of the achievement instruments. The second part of the report summarises the science and mathematics achievement of the South African Grade 12 students and sketches the students' background information.

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 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 of different national systems 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): the intended, the implemented and the attained curriculum. 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 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.*, 1996:37)

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, that are intended for, implemented in, and attained during students' schooling experiences. This framework allows for a given assessment question (item) or learning material to be categorised in detail. The items can be categorised in terms of subject matter (e.g. proportionality), performance expectations (e.g. problem-solving) and perspectives (e.g. positive attitudes towards mathematics, science and technology). The detailed categories within the science and mathematics frameworks differ, but the structure and rationale of the two 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

Content aspect
- Numbers
- Measurement
- Geometry: position ...
- Geometry: symmetry ...
- Proportionality
- Functions, relations, equations
- Data, probability, statistics
- Elementary analysis
- Validation and structure
- Other content

Performance expectations aspect
- Knowing
- Using routine procedures
- Investigating and problem solving
- Mathematical reasoning
- Proportionality
- Communicating

Perspective aspect
- Attitudes
- Careers
- Participation
- Increasing interest
- Habits of mind

(Robitaille *et al.* 1993:46)

Figure 1:3 Three aspects and major categories of the science framework

Content aspect
- Earth sciences
- Life sciences
- Physical sciences
- Science, technology, mathematics
- History of science and technology
- Environmental issues
- Nature of science
- Science and other disciplines

Performance expectations aspect
- Understanding
- Theorizing, analyzing, solving problems
- Using tools, routine procedures
- Investigating the natural world
- Communicating

Perspectives aspect
- Attitudes
- Careers
- Participation
- Increasing interest
- Safety
- Habits

(Robitaille *et al.* 1993:46)

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. The perspectives are attitudes that students develop by exposure to a particular curriculum.

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 in mathematics and science. It is also suited to the complex, integrated performances expected from students in the new forms of assessment emerging with the curricular reforms.

1.4 Students tested in TIMSS

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

In the context of the South African study, Grades 4 and 5 represented Population 1. At the time of the investigation the mother tongue was the medium of instruction up to Grade 2. This population was not included as no resources (human and financial) were available for translations into other languages. Grade 7 and Grade 8 represented Population 2 and Grade 12 represented Population 3. Grades 7, 8 and 12 were all tested in South Africa, allowing South Africa to be included in the Population 2 and Population 3 of TIMSS. This report focuses on the achievement of this last group of students.

The students in Grade 12, 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 Grade 12 students who were tested wrote a general science and mathematics literacy achievement test. No specialised tests were written.

1.5 General design of TIMSS

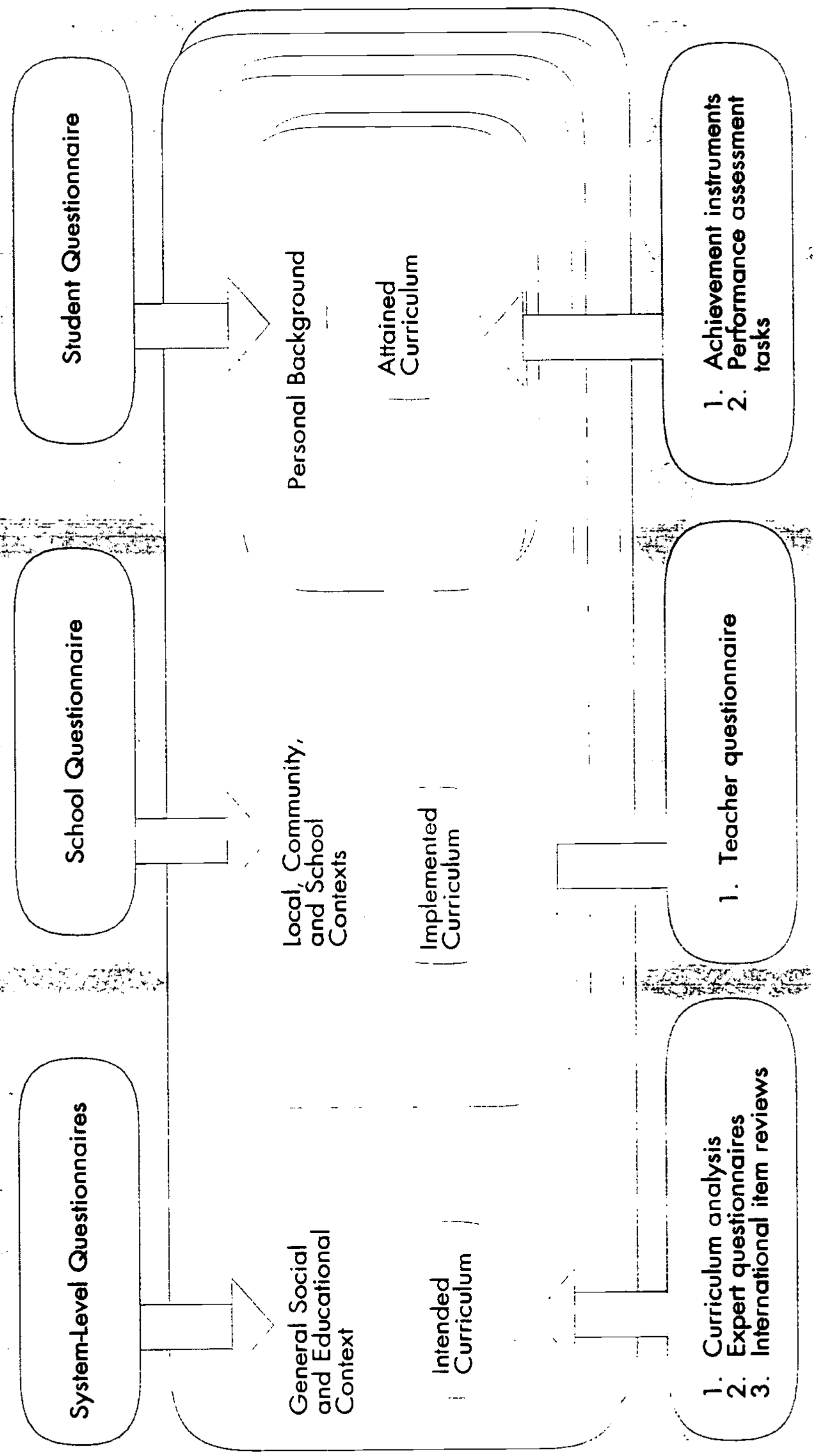
The TIMSS research was conducted at three levels: the curriculum analysis level, the achievement tests level and the questionnaires level. Figure 1.4 illustrates the instruments (achievement tests and questionnaires) that were used.

Four questionnaires were administered at the national (system) level at various times in the course of the study. Two of these questionnaires dealt with the organisational structure, courses, demographics 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 by 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. Data at the national level 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 enrolment, demographics and subject selection, as well as 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

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



(Robitaille *et al.*, 1996:50)

questionnaire was at Population 1 level; Population 3 had no teacher questionnaire. The questionnaires included five topics: the 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. Each included questions on the student's background, opinions and attitudes to mathematics and science.

1.6 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 since the test conditions can be standardised, the cost is low and they can be machine-scored. However, there has recently been a 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 Grade 7, 8 and 12 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.

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. The first digit was coded for correctness of the answer and the second digit was a code to identify the quality 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 (Martin and Kelly, 1996:7-7).

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.

1.7 Sampling for the TIMSS Population 3 study

The sampling procedure was designed and strictly controlled by the international study group to ensure the statistical validity of the study. A random sample of students, representative of the country, was to be selected. The sample of schools that was used for Population 3 (grade 12) was the same as that used for Population 2. This was largely a financial decision, making the fieldwork more time and cost-effective.

The sample for Population 2 was randomly drawn from all schools that had more than 40 students in Grade 8 (Std 6) in 1991. This was done as follows (Claassen, 1995)

- For the Western Cape, schools were arranged from the smallest to the largest, according to the number of students in Grade 8.
  - Immediately below the list for the Western Cape, a similar list for the Northern Cape schools was compiled, but this time arranged from the largest to the smallest in terms of Grade 8 student numbers.
  - This process was continued for the other seven provinces.
  - An appropriate interval was determined so that 150 schools would be chosen from 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 (as determined above), one of the Grade 12 classes was randomly selected and the tests administered to that class only.

1.8 Administration of Population 3 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 students included for analysis are indicated below in Table 1.1. Some of the selected schools were unable to participate for various reasons. The number of classes participating in the study whose scores were reflected in the international reports, was 90. The number of participating students whose scores were included in the international study was 2 757.[4] 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.

4 3 695 students were tested in total, but after exclusions (such as students who were repeating Grade 12) the figure dropped to 2 757.

Table 1.1: Number of students participating in TIMSS Population 3 per province[5]

Province	Number of Grade 12
Eastern Cape	570
Free State	204
Gauteng	368
Kwazulu-Natal	534
Mpumalanga	292
Northern Province	358
North West	397

5 Twenty-five students were tested in the Western Cape and nine in the Northern Cape. There were problems in gaining access to schools in the Western Cape, making the realised sample substantially lower than the intended sample. Due to the low density in the Northern Cape province, initially a proportionately smaller sample was drawn. When access to a number of schools was denied, the size of this sample was significantly affected.

Chapter 2

Background to Population 3 results

Key Points

- There was a great variety in the nature of the upper-secondary education systems of the countries participating in Population 3.
- South Africa's TIMSS coverage index[6] was one of the lowest.
- South Africa had the lowest proportion of people living in urban areas.
- South Africa had the second highest public expenditure (as a percentage of the gross national product) on education.

6 The TIMSS coverage index was calculated for each country and was "an estimate of the percentage of the school-learning age cohort covered by the TIMSS final-year students sample" (Mullins, I.V.A. *et al.* 1998:17).

Chapter 2

Background to Population 3 results

2.1 Introduction

The concerns on the part of industry and within communities about mathematics and science education are increasing. There is a growing need for better qualified workers in the fields of science and technology to enter the workplace, and an increased interest in what school-leavers know and are able to do in mathematics and science.

The TIMSS data for the final-year students can be used as a basis for determining the concepts and understanding of these students in the fields of mathematics and science. It is also a means to establish how effectively these students will use their knowledge and understanding once they have left secondary school.

The TIMSS results and findings concerning this age group may be used in several ways. It is hoped that this information will be used constructively to inform policy makers and practitioners in order to reconstruct and develop education in South Africa and other countries. Furthermore, it may be used to mobilise communities to support the implementation of new policies in the fields of mathematics and science in the schools and training institutions, as well as to support students wishing to enter these fields. TIMSS also provides a means of comparing education systems and policies. This should be more important to policy makers and practitioners than simply comparing the final rank order of the countries participating. The similarities and differences between different countries' education systems, made apparent by the data collected, have served in the past to motivate changes in various governments' policies with regard to mathematics and science.

2.2 Countries participating in TIMSS Population 3

The countries that took part in the mathematics and science literacy tests were the following:

- Australia
- Austria
- Canada
- Cyprus
- The Czech Republic
- Denmark
- France
- Germany
- Hungary
- Iceland

- Israel
- Italy
- Lithuania
- The Netherlands
- New Zealand
- Norway
- The Russian Federation
- Slovenia
- South Africa
- Sweden
- Switzerland
- United States of America

2.3 Students tested in Population 3

There was a great variety in the nature of the upper-secondary education systems of the countries participating in Population 3. Different types of upper-secondary education were offered in different countries and these were in the form of

- schools offering comprehensive education,
- schools offering a single track e.g. vocational training, and
- schools offering different tracks within the school, e.g. academic, vocational, technical.

Of course there was an additional complication as the definition of academic, vocational and technical also differed from country to country. Defining the final-year of schooling across all the participating countries was also problematic, as there were variations in the grades representing the final year of schooling.

Therefore, it is important to understand the nature of the different upper-secondary education systems in order to make valid comparisons between countries.

2.4 TIMSS coverage index (TCI)

One of the important differences between education systems of different countries is the proportion of the age group that completes upper-secondary education. Since the 1960s there has been a significant increase in the number of students achieving this level.

The TIMSS coverage index (TCI) was calculated for each country in order to provide information about the number of pupils in the school-leaving age group still at school, and that represented the TIMSS sample. The TCI is "an estimate of the percentage of the school-leaving age cohort covered by the TIMSS final-year students sample" (Mullis *et al.*, 1998:17). "The TCI reflects the exclusion from the sample, of, for instance, students who were omitted who had dropped out of school, tracks or educational programmes which were not covered by the TIMSS sample. The TCI was calculated by "forming a ratio of the size of the student population covered by the TIMSS sample, as estimated from the sample itself, and the size of the schooling-leaving age cohort, which was derived from official population census figures of each country ''(Mullis, *et al.*, 1998:17).

Therefore, countries with high TCIs have most of their students of school-leaving age still at school and have covered this population with their TIMSS sample. On the other hand, countries with low TCIs have fewer students in school or have excluded some components of their system from their sample.

In the table below, the TCIs for each country are given. The section of the school-leaving group not covered by the sample is presented in two groups, these being the systems components excluded and secondly these students electing not to complete the upper-secondary education. As can be seen from Table 2.1, South Africa has a TCI of just 48,9 %, indicating that the TIMSS sample of final-year students covered just less than half the school-leaving age group.

2.5 Characteristics of countries participating in TIMSS Population 3

The results of comparative studies should also be seen in the broader context in which students are educated and the factors that play a role. Some of the demographic factors are presented for each country in Table 2.2. This table includes information on the size and density of the population, the size of the country, the proportion of urban dwellers. South Africa is the least urbanised of the countries tested and has the lowest percentage of students in secondary school.

Table 2.3 presents information concerning public expenditure on education. It includes information on the gross national product (GNP) per capita and public expenditure as a percentage of the GNP. As can be seen, South Africa's GNP is the lowest among the countries participating in TIMSS. However, the percentage of GNP spent on education in South Africa is second only to that of Norway.

Table 2.1: TIMSS coverage index

Country	TIMSS coverage index (%)	Sample exclusions (%)	Others not covered (%)	Notes on exclusions
Australia	68,1	4,0	27,9	
Austria	75,9	16,8	7,3	Colleges lasting less than 3 years
Canada	70,3	19,5	10,2	Ontario students graduating in December excluded
Cyprus	47,9	13,5	38,6	Private and vocational school excluded
Czech Republic	77,6	0,0	22,4	
Denmark	57,7	1,3	41,0	
France	83,9	0,9	15,3	
Germany	-	-	-	
Greece	10,0	56,8	33,2	Only students having taken advanced mathematics and physics included
Hungary	65,3	0,1	34,6	
Iceland	54,5	0,0	45,4	
Israel	-	-	-	
Italy	51,5	0,5	48,0	
Latvia	3,0	16,8	80,3	Only students having taken physics
Lithuania	42,5	0,0	57,5	
Netherlands	78,0	20,6	1,4	Short vocational and apprenticeship programmes excluded
New Zealand	70,5	0,0	29,5	
Norway	84,0	1,3	14,8	
Russian Federation	48,1	36,3	15,7	Vocational schools and non-Russian speaking students excluded
Slovenia	87,8	0,0	12,2	
South Africa	48,9	0,0	51,1	
Sweden	70,6	0,0	29,4	
Switzerland	81,9	2,1	16,0	
United States	63,1	0,6	36,4	

(Mullis, I.V.A. *et al.*, 1998:18)

Table 2.2: Demographic characteristics of TIMSS countries

Country	Population Size (1,000)	Area of Country (1000 square kms)	Density (population per square km)	Percentage of population living in urban areas	Percent in Secondary School
Australia	17 843	7 731	2,29	84,8	84
Austria	8 028	84	95,28	55,5	107
Canada	29 248	9 976	2,9	76,7	88
Cyprus	726	9	77,62	53,6	95
Czech Republic	10 333	79	130,99	65,3	86
Denmark	5 205	43	120,42	85,1	114
France	57 928	552	104,56	72,8	106
Germany	81 516	357	227,39	86,3	101
Greece	10 426	132	78,63	64,7	99
Hungary	10 261	93	110,03	64,2	81
Iceland	266	103	2,56	91,4	103
Israel	5 383	21	252,14	90,5	87
Italy	57 120	301	189,36	66,6	81
Latvia	2 547	65	40,09	72,6	87
Lithuania	3 721	65	57,21	71,4	78
Netherlands	15 381	37	409,30	88,9	93
New Zealand	3 493	271	12,78	85,8	104
Norway	4 337	324	13,31	73,0	116
Russian Federation	148 350	17 075	8,7	73,2	88
Slovenia	1 989	20	97,14	62,7	85
South Africa	40 539	1 221	32,46	50,5	77
Sweden	8 781	450	19,38	83,1	99
Switzerland	6 994	41	168,03	60,6	91
United States	260 650	9 809	27,56	76,0	97

(Mullis, I.V.A. *et al.*, 1998:22)

Table 2.3 Public expenditure at primary and secondary levels in TIMSS countries

Country	Gross National product per capita (US dollars)[7]	Public expenditure on education as % of gross National Product
Australia	17 890	3,69
Austria	24 950	4,24
Canada	19 570	4,62
Cyprus	10 380	3,60
Czech Republic	3 210	3,75
Denmark	2 8110	4,80
France	23 470	3,61
Germany	25 580	2,43
Greece	7 710	2,27
Hungary	3 840	4,31
Iceland	24 590	4,77
Israel	1 4410	3,72
Italy	19 270	2,89
Latvia	2 290	2,85
Lithuania	1 350	2,18
Netherlands	21 970	3,3
New Zealand	13 190	3,15
Norway	26 480	5,26
Russian Federation	2 650	-
Slovenia	7 140	4,2
South Africa	3 010	5,12
Sweden	23 630	4,92
Switzerland	37 180	3,72
United States	25 860	4,02

(Mullis, I.V.A. *et al.*, 1998:23)

7 These figures are estimates for 1994.

Chapter 3

Student background

Key Points

- A large proportion of South African students wrote the literacy test in their second or third language.
- The average age for South African Population 3 students was 20.1 years.
- The majority (85 %) of students in SA were enrolled for biology. About 70 % had included mathematics in their subject choice.
- Of the South African sample, 95 % had intentions of studying further, and of these, 75 % planned to go to university.
- The most popular area nominated for further study by South African students was engineering.
- Students in general prefer biology to physics and chemistry.
- The greatest proportion of students in South Africa reported that the highest educational level attained by either parent was primary school and then, to a lesser extent, secondary school.
- Close to 60 % of students in South Africa had less than 26 books in the home.
- In South Africa 92 % of students indicated that they did not have a computer at home.
- South African students reported spending five hours a day on homework – the most time compared to all other countries.

Chapter 3

Student background

3.1 Introduction

To help explain the mathematics and science literacy achievement results across countries, TIMSS elicited a range of descriptive information from various educational roleplayers. One component of sketching the contexts supporting education in different countries was to gather information from students themselves concerning their attitudes, perceptions, backgrounds and in- and out-of-school activities. As these can impact on academic performance it is important to understand the conditions that support or limit student achievement.

This chapter examines students' attitudes, perceptions and background information given in response to several questions posed to them. A number of these questions revolved around their current training and their plans for future education. In order to examine the impact that the students' home and social environments may have on academic achievement, some of the questions looked at the issue of educational resources in the home. This is particularly relevant to the South African case as disparities in resources have pervaded the South African society for many years. In addition, the use and effectiveness of both calculators and computers remain debates in mathematics and science education, and a number of questions addressed these issues. A further group of questions involved whether or not students typically spend their out-of-school time in ways that support their in-school academic performance.

3.2 Student biographical information

Of the South African student sample, 51 % were female and 49 % were male.

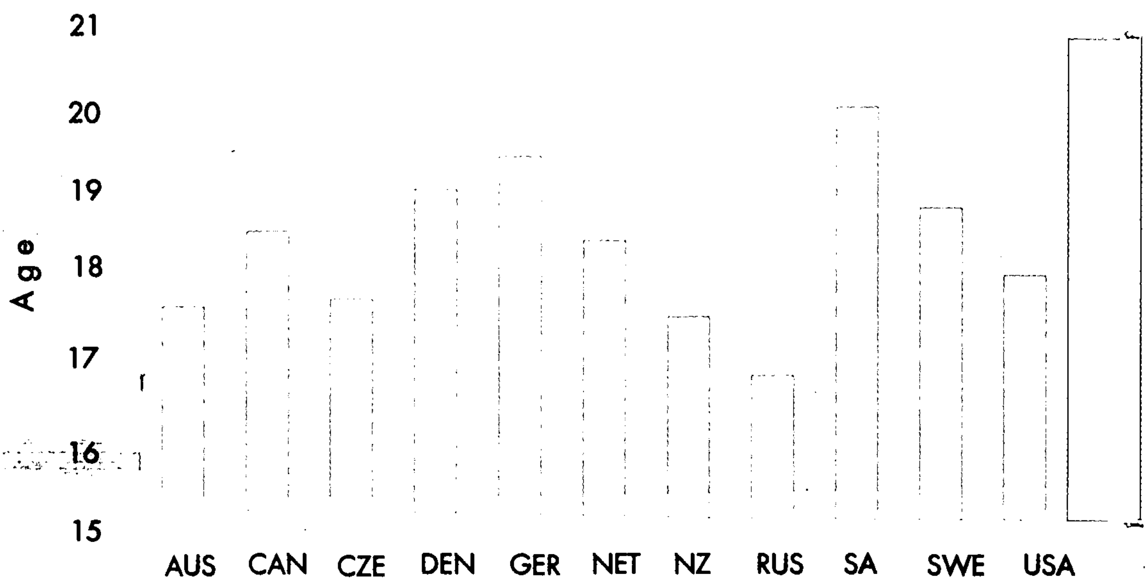
It appears that a large proportion of the South African students who wrote the literacy test did so in their second or third language. About 19 % indicated that they *always* or *almost always* spoke the language of instruction at home, whereas approximately 72 % indicated that they *sometimes* spoke the language of learning at home. The remaining 9 % *never* spoke the language of instruction at home. In the South African context language is likely to be a factor influencing performance. Further comparative analysis of achievement levels with other countries in which students wrote the performance tests in their second or third language may uncover some interesting findings.

When asked how many people lived in their home the highest proportion of South African students reported about 5-6 people (about 17 % for each). A slightly lower proportion indicated that about 4, 7 or 8 people lived in their home. Small households of three people or fewer were much less common. It is also interesting that a much higher proportion of students lived with their mothers (83 %) than with their fathers (48 %).[8] About 80 % of students reported that they were residing at home as opposed to living with relatives away from home.

8 Students who had their mothers living at home with them may also have had their fathers at home (the 48 % could be included in the 83 % value). A number of other people may also have been living in their house.

The average age of students participating in the mathematics and science literacy study is shown in Figure 3.1.

Figure 3.1: The average age of population 3 students[9]



Apart from Iceland (not shown in Figure 3.1), which had an average age of 21,2, the South African students appear to be above the average age in comparison to all the other countries. Most countries' participating students were roughly 17-19 years old. That South African students were among the oldest can be attributed to a number of factors such as late entry into school, and repetition of the earlier grades.

3.3 Educational aspirations

3.3.1 Subject preferences

The approach in many countries is for students in the upper secondary classes either to select or to be allocated to educational tracks that fit in with their abilities or interests. As has already been alluded to, because of these cross-national differences it is difficult to define international categories that are comparable. Four broad categories, however, were distinguishable – academic, technical, vocational and general. South Africa was classified as having an academic programme. All 22 participating countries offered an academic programme and a large majority (17) also offered a vocational one.

9 The countries represented in the graph are Australia, Canada, the Czech Republic, Denmark, Germany, the Netherlands, New Zealand, the Russian Federation, South Africa, Sweden and the United States of America.

Across a broad spectrum of students participating in the study it is interesting to determine whether students elect mathematics and science as part of their curriculum. Table 3.1 illustrates that almost 70 % of students in the South African sample included some type of mathematics course during their final year of schooling. Internationally the proportion of students taking mathematics varied considerably from 54 - 100 %. In most countries, including South Africa, more males than females reported that they were currently taking mathematics. In South Africa 67 % of females and 71 % of males indicated that they were enrolled for mathematics.

Table 3.1: Proportions of final-year South African students taking mathematics

Level of mathematics taken	%
Did not take mathematics up to std 10	29,7
Functional grade mathematics std 10	3,9
Standard grade mathematics std 10	39,8
Higher grade mathematics std 10	26,5

Compared to the enrolment in mathematics, fewer students in the sample were enrolled for physical science (more likely than not this covered physics and chemistry). Just over 50 % of the South African sample took physical science. The same proportion of males and females reported taking science in South Africa. There were fewer countries showing substantial differences in the percentages of males and females taking science than there were countries showing gender differences in numbers of pupils taking mathematics.

Table 3.2: Proportions of South African students enrolled for science courses

Level of science course taken	Most advanced course taken in physics (%)	Most advanced course taken in chemistry (%)
Did not take physical science up to std 10	45,6	46,7
Std 10 functional/standard grade physical science	21,7	21,1
Std 10 higher grade physical science	32,6	32,1

Approximately 85 % of students in the TIMSS sample in South Africa were enrolled for biology. This could be explained by the high proportion of schools traditionally offering biology as a compulsory subject, the fact that students found the subject appealing or that students perceived it to be an easy subject to pass.

The proportion of students taking geography was similar to that taking physical science. Only approximately half of the South African sample was studying geography in their final year of school.

3.3.2 Future study plans

A few questions focused on the prospect of further study. Ninety-five percent of the South African sample reported that they had intentions of pursuing tertiary studies. Of that cohort, 75 % planned to go to university.[10] Along with Slovenia this statistic constituted the highest percentage of students intending to go to university. The fact that considerably fewer students in other countries elected to go to university can be explained by the fact that numerous countries have well-developed vocational or technical programmes, and students then plan tertiary studies in similar programmes. In general, the students who intended studying at a university (as opposed to vocational training) showed higher achievement scores in mathematics and science literacy.

Students were asked to indicate their proposed career directions. The most popular area nominated for further study by South African students (see Table 3.3), was engineering (all the conventional engineering domains). The business field, which includes accounting, marketing, finance, administration and management, was the second most popular choice. The health sector also appeared to be appealing to students, with a similar proportion of students hoping to study in non-science- related fields. The fields of chemistry and physics were the least attractive to students. Only 1,8 % and 0,9 % of students reported any interest in studying further in chemistry and physics respectively.

Table 3.3: Students' preferences concerning intended future study

Area of intended study	%
Biological sciences (e.g. botany, ecology, zoology)	10,7
Business (e.g. accounting, marketing, finance, administration, management)	17,2
Chemistry (e.g. chemistry, biochemistry)	1,8
Computer and Information sciences (e.g. sytems analyst)	6,5
Earth sciences (e.g. geology, oceanography)	3,0
Engineering (e.g. chemical, civil, electrical, mechanical engineering)	18,4
Health occupations (e.g. dental assistant, practical nursing, veterinary assistant, X-ray technology)	11,9
Health sciences (e.g. dentistry, medical doctor, optometry, pharmacy, physical therapy, registered nursing, veterinary medicine)	13,6
Mathematics (e.g. calculus, statistics)	4,6
Physics (e.g. astronomy, physics)	0,9
Other fields of study	11,5

10 Due to difficulties in arriving at a consistent definition of "university" internationally, cross-national comparisons were somewhat inappropriate.

3.4 Students' attitudes towards mathematics and science

3.4.1 Previous performance in mathematics and science

Table 3.4: Students' reports on how well they perform in mathematics and science

	Doing well in mathematics				Doing well in science			
	Agree or strongly agree		Disagree or strongly disagree		Agree or strongly agree		Disagree or strongly disagree	
Country	% of students	Mean mathematics literacy score	% of students	Mean mathematics literacy score	% of students	Mean science literacy score	% of students	Mean science literacy score
Australia	72	544	28	477	73	554	27	470
Canada	67	542	33	476	75	548	25	489
Czech Republic	55	487	45	441	71	500	29	463
Denmark	76	566	24	498	72	535	28	469
Germany[11]								
Netherland	63	581	37	527	63	570	37	540
New Zeal	66	557	34	456	68	557	32	471
Russ. Fed	58	494	42	441	78	489	22	457
South Africa	58	367	42	353	73	349	27	366
Sweden	62	583	38	507	66	586	34	515
USA	76	476	24	423	83	491	17	440

(Mullis, *et al.*, 1998:95)

Students were asked about their perceptions concerning how well they usually did in mathematics. In general, students expressed positive perceptions of their progress in mathematics and science. In all countries, the majority of students agreed that they were doing well in both subjects. Students' academic performance appears to support their perceptions – the average performance of those who claimed that they usually did well generally exceeded the performance of those who disagreed. However, whereas most countries had a considerable differential in mean performance scores for those who thought they usually did well as opposed to those that did not, in the case of South Africa this differential was very small for mathematics and the trend was reversed for science. In other words, the trend for mathematics was not that evident in South Africa, possibly suggesting that students' perceptions had little effect on their achievements and that, in general, they upheld unrealistic perceptions of their competencies. The figures for science indicate that those who did not think that they usually did well actually outperformed those who thought that they did well, and may once again point to unrealistic perceptions on the part of students.

The gender differences in self-perceptions indicated a strong similarity between males and females. If any differences were evident, it was always a greater percentage of males than females asserting that they were doing well.

11 Germany had data available for < 50% of students

3.4.2 Students' perceptions about liking mathematics and science subjects

Students were asked how much they liked or disliked the science-related subjects for which they were enrolled. Their responses for liking mathematics are set out in Table 3.5. In almost all countries the majority of students reported that they liked mathematics to some degree. In every country, a positive relationship was observed between liking mathematics and achievement in mathematics. Those who disliked mathematics performed worse than those who expressed a liking for the subject. In general, there was no significant difference between males and females in their degree of liking mathematics.

Table 3.5: Students' reports on how much they like mathematics

	Dislike a lot		Dislike		Like		Like a lot	
Country	% of students	Mean mathematics literacy score	% of students	Mean mathematics literacy score	% of students	Mean mathematics literacy score	% of students	Mean mathematics literacy score
Australia	14	455	25	513	47	538	14	578
Canada	17	476	22	501	46	529	15	573
Czech Republic	19	435	48	447	28	501	5	575
Denmark	7	460	14	506	44	551	34	586
Germany	xx[12]	xx	xx	xx	xx	xx	xx	xx
Netherland	-[13]	-	-	-	-	-	-	-
New Zeal	18	468	29	491	42	547	11	592
Russ. Fed	6	442	32	449	52	480	10	511
South Africa	8	334	14	363	40	367	38	372
Sweden	13	468	29	521	42	574	16	625
USA	13	414	21	446	45	465	21	509

(Mullis, *et al.*, 1998:99)

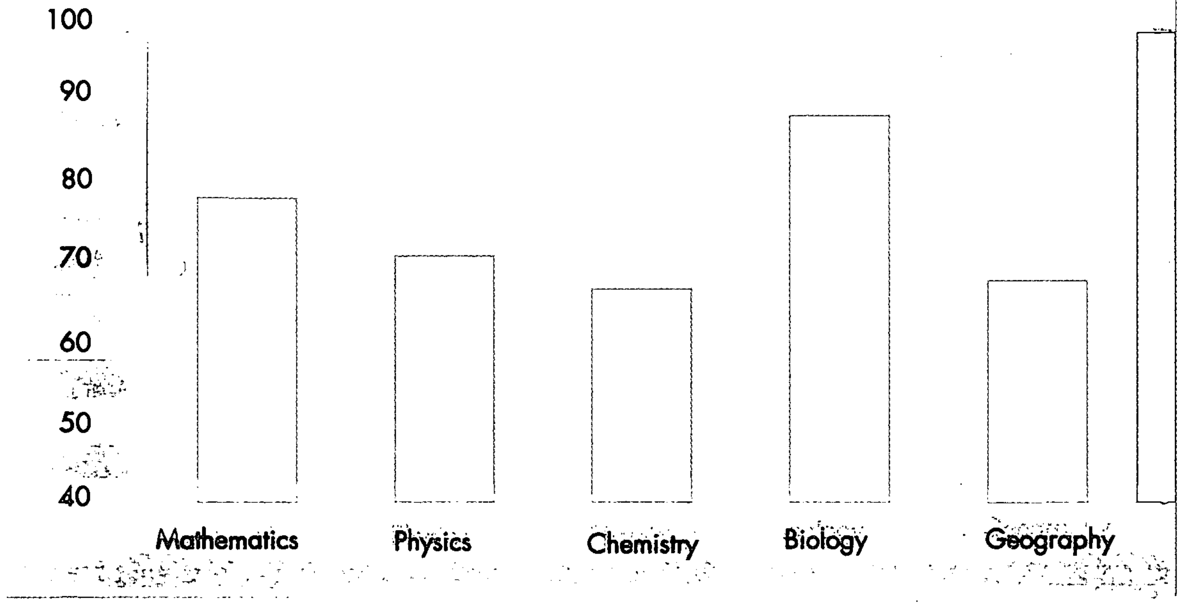
Of all the sciences, students in almost all countries indicated higher levels of liking biological science than chemistry and physics. This was also true for South Africa and from Figure 3.2 it can be seen that the majority of South African students stated that they liked biology. Chemistry and physics seemed less appealing to students, which fits their preferences for further study as discussed in section 3.3.2 of this chapter.

There were differences between the males' and females' liking of the science subjects. In the majority of countries female students reported liking biological science more than male students did. The opposite was true for physics, where more males liked physics than females. Further research to uncover the reasons for these findings may reveal some interesting insights.

12 An "xx" indicates that data was available for < 50 % of students.

13 A dash (-) indicates that data were not available.

Figure 3.2: South African students' reports on liking[14] science subjects



3.5 Educational resources in the home

Parental education is frequently a useful indicator of the level of support for academic endeavour, and is often associated with student achievement. Students were asked to indicate the highest level of education completed by their parents. TIMSS revealed a clear positive correlation cross-nationally between parents' education and students' mathematics and science literacy. Final-year students whose parents had had more education had higher mathematics and science literacy scores. Along with Austria and the Netherlands, South Africa had the lowest proportion (11 %) of students whose parents had completed university. In the various countries this percentage ranged from 11 - 44 %, with Canada having the highest proportion. Most students in South Africa reported that the highest level attained by either parent was to complete primary school. The bulk of the South African parents had either completed primary school or partly completed secondary school, and it is possible that the level of parental education constitutes one of the factors limiting academic performance.

14 This refers to students who indicated that they either *liked* Mathematics or *liked it a lot.*

Table 3.6: Parental educational levels of South African students

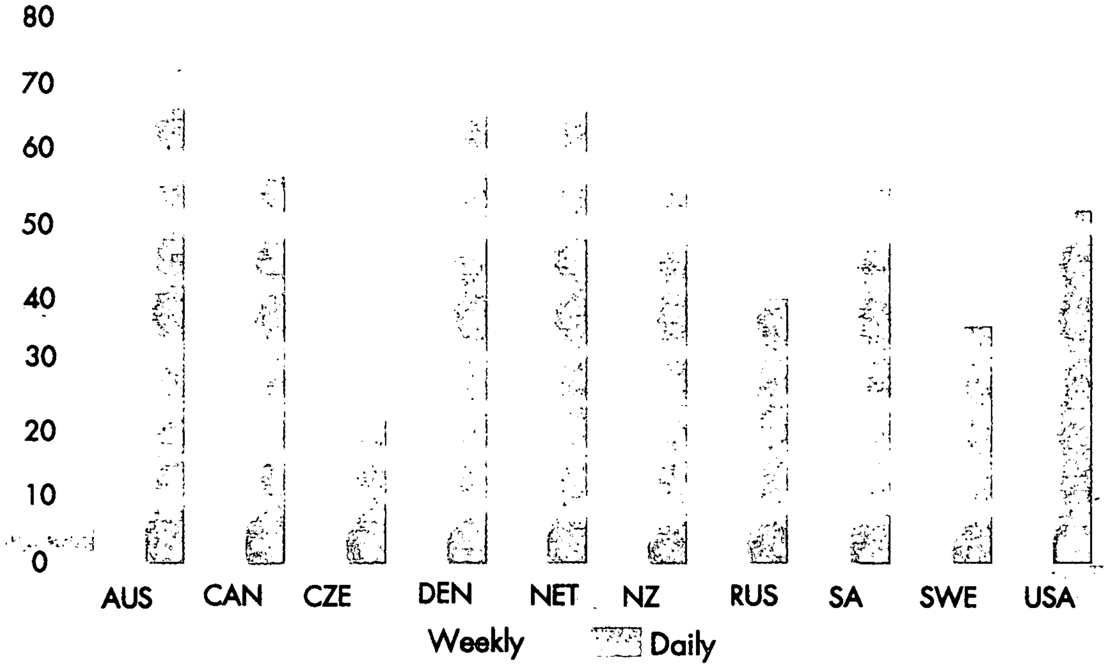
	Father	Mother
Completed primary school	24,6	31,5
Partially completed secondary school	18,8	22,8
Completed secondary school	13,3	14,2
Completed vocational/technical education after secondary school	7,6	5,0
Partly completed university study	2,6	1,6
Completed university study	6,2	4,8
Don't know	26,9	20,3

That such a high proportion of students did not know the educational level of their parents was surprising, but a similar finding was established in Population 2. Perhaps it is due to the fact that, in general, parents with very low educational levels avoid discussing the issue.

The number of books in the home can be an indicator of a home environment that values literacy and the acquisition of knowledge, and offers general academic support. The rationale for this question was to gain information about the relative importance of academic pursuits in the students' home environments, rather than to determine the actual number of books in the home. Close to 60 % of students in South Africa had less than 26 books in their home. This means that the bulk of sampled students in South Africa had only a few books in their home. Compared to other countries South Africa had the highest proportion (almost 60 %) of students reporting that they had less than 26 books in the home. Most countries had between 5 and 23 % of students who reported having this amount of books at home. At the other end of the scale more than 40 % of the students in countries such as Australia, Denmark, Norway and Sweden reported more than 200 books in their homes.

Asked whether they had calculators in their home almost 47 % of South African students reported that they had, whilst about 54 % did not. In terms of how often calculators are used at school, home or anywhere else, the majority of students in every country indicated that they use it *weekly* or *daily*. Additionally, students in the majority of countries said that they used calculators for some purpose on a daily basis.

Figure 3.3: Students's reports on the frequency of calculator use at school, home or anywhere else



In South Africa 92 % of students indicated that they did not have a computer at home. Concerning the frequency of computer use at school, home or anywhere else, 81 % of South African students said that they *rarely* or *never* used a computer. In six other countries including Cyprus, the Czech Republic, Hungary, Italy, Lithuania and Norway, more than 50 % of students reported that they *rarely* or *never* used a computer, although South Africa showed the highest proportion by far.[15] A number of countries such as Australia, Canada, the Netherlands, New Zealand, Switzerland and the United States had the highest proportion of students indicating that they used computers *daily*. This proportion ranged from 28 - 31 %.

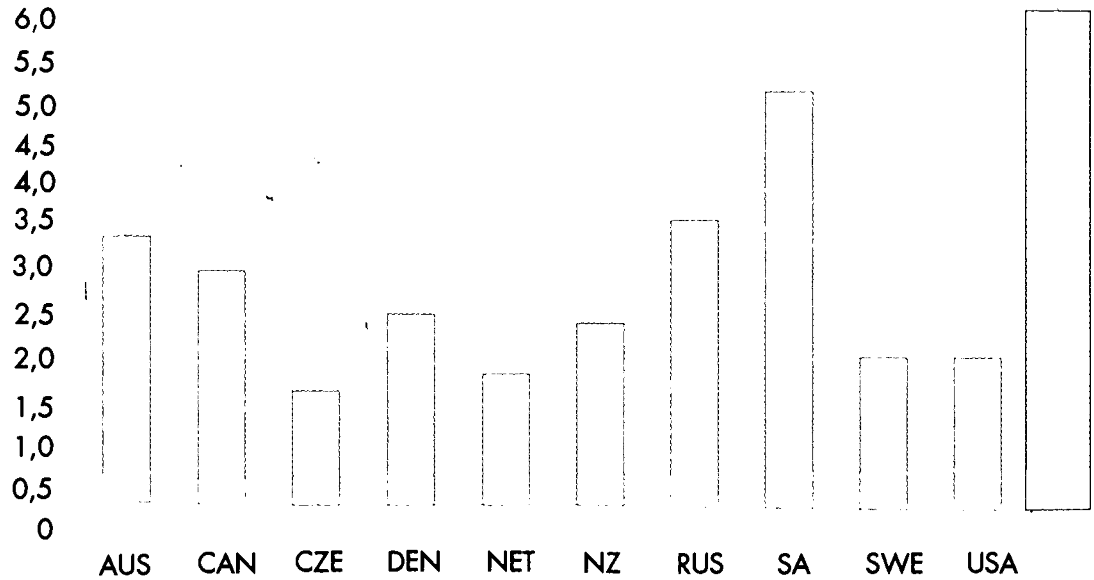
15 The next highest proportion was 69 % (Lithuania).

3.6 Use of out-of-school time

3.6.1 Homework

Young people spend a large proportion of their time outside school. Some of this time is spent furthering academic development. Concerning homework, students in most countries reported spending, on average, between two and three hours a day on homework. South Africa stood out in that its students reported spending about five hours a day on homework (see Figure 3.4). This was the highest average time devoted to homework, compared to all the participating countries.

Figure 3.4: Average[16] hours spent on doing homework per day

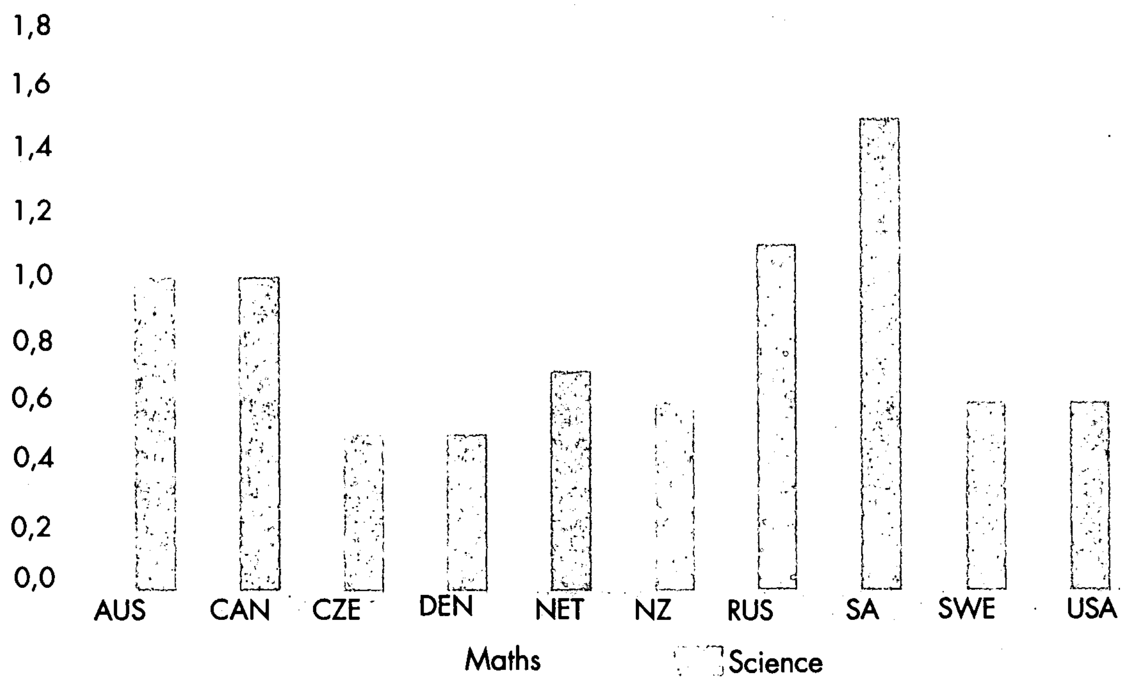


The relationship between time spent doing homework and students' average mathematics and science literacy performance was inconsistent and trends were difficult to identify. In a few countries a linear relationship was evident but, as in the South African case, more time devoted to homework did not result in higher scores. This can be seen as one of the contradictory features emerging from the South African data and raises questions concerning students' ability to estimate as well as other possible explanations. More frequently, the highest achievement was associated with a moderate amount of homework per day. This optimal level appeared to be between one and three hours.

16 The value was calculated based on the following: No time = 0, less than 1 hour = 0.5, 1-2 hours = 1.5, 3-5 hours = 4, more than 5 hours = 7.

The amount of time students reported spending on studying or doing homework each day in mathematics and science also revealed some interesting peculiarities. An average of 0.5-1 hour of homework in both subject areas was reported in nearly all countries. South African students, on the other hand, spent an average of 1.7 hours per day on mathematics homework and 1.5 hours on science homework. In each case this was the highest proportion of time spent on homework compared to all the other countries. Despite spending a considerable amount of time on homework in general, and on specific subjects, this additional out-of-school work does not appear to enhance performance levels for South African students. Perhaps the low performance in the literacy test says something about students' general and applied knowledge in mathematics and science. It is likely that South African students are accustomed to syllabus-related work and more particularly, specific questions which are commonly practised in class and appear in examinations. The TIMSS literacy test comprised applied word problems and not the conventional question types that students are ordinarily faced with in their school settings. Thus, the low performance of South African students can in part be explained by their generally low literacy levels in mathematics and science, as well as their competencies in handling tests which contain largely word problems.

Figure 3.5: Average hours spent on mathematics and science homework per day



3.6.2 Other activities

Students were also asked about the various ways in which they spent their out-of-school time. The activity occupying more of South African students' time than all other activities was *doing jobs at home* (see Table 3.5). Compared to students in other countries, South African students spent the most time on this task. The activity that absorbed the least amount of South African students' time was playing computer games. Eighty-four percent indicated that they spent no time on this activity. Another activity which was not a significant part of South African students' lives was working at a paid job. Seventy-five percent of the students indicated that they did not engage in this activity or spent little time on this activity after school. As alluded to earlier, it appears that South African students spend far more time on homework than on other out-of-school activities.

Table 3.7: South African students' reports on how they spend their leisure time

Activity	Time (Average hours per day)
Watching television or videos	1,2
Playing computer games	0,2
Spending time with friends outside of school	1,1
Doing jobs at home	2,2
Working at a paid job	0,9
Playing sports	1,3
Reading a book for enjoyment	1,3

3.7 Conclusion

This chapter examined the background features that surround students' learning and home environments. From the TIMSS literacy study definite positive relationships were identified e.g. academic performance is supported by student perceptions and liking mathematics is positively related to higher achievement. In a number of ways South Africa stands out – their students were almost the oldest and they spent the most time on household chores, students' homes boasted far fewer books, and students' parents had close to the lowest educational levels. These unique features (among others) are likely to limit academic performance considerably. In addition, a number of surprising or contradictory elements have emerged from the South African analysis. These include the excessive amount of time spent on homework without any return on performance level, and students' perceptions of their good performance in mathematics and science and the disjuncture with their performance in the literacy test. The identification of the dominant factors influencing the low literacy levels in mathematics and science, and how these levels can be improved, are important components of the detailed analysis of TIMSS that will be undertaken in later research reports.

Chapter 4

Overall achievement in mathematics and science literacy

Key points

- The overall scores were significantly lower than those of students in other countries,
- South Africa was the only country with no significant difference between the performance of boys and girls.
- Free State, Gauteng and KwaZulu-Natal performed consistently better than the other 6 provinces.
- South African students with English and Afrikaans as a home language performed significantly better than those students with other home languages.

Chapter 4

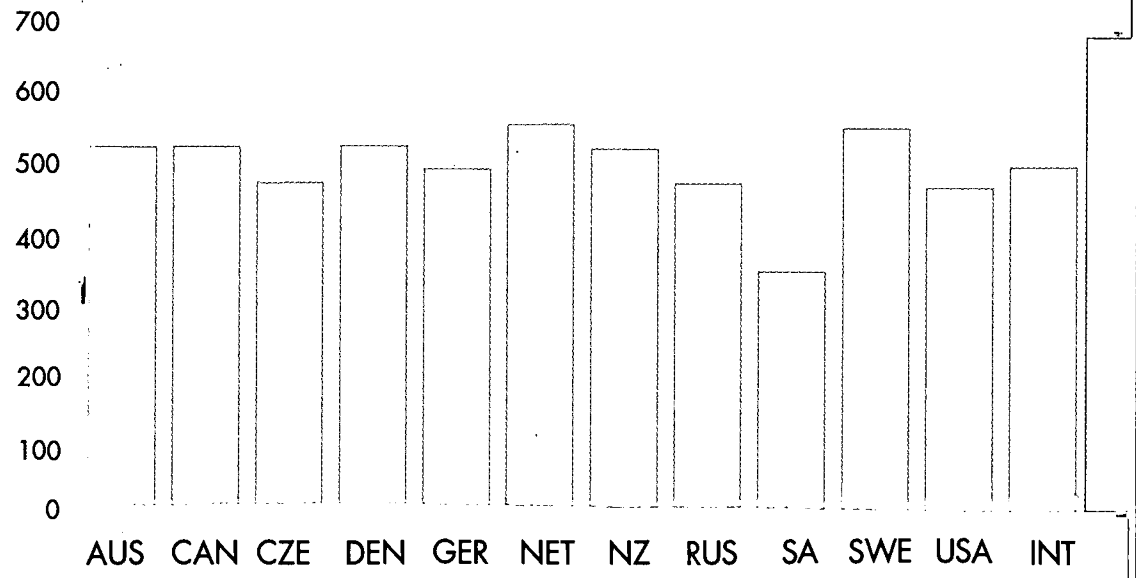
Overall achievement in mathematics and science literacy

4.1 National mathematics and science literacy achievement

In this chapter, the results of the performance of the South African Grade 12 students are presented and compared to with those of students in ten other countries participating in TIMSS. In total, 22 countries participated in TIMSS Population 3. The ten countries were selected from the top-scoring, middle-scoring and bottom-scoring countries on the achievement results scale. These results reflect the students performance in the mathematics and science literacy test. This test was designed to measure the mathematics and science literacy of all final-year students, regardless of their school curriculum. In other words, the test was applied to both students taking a science subject[17] and those who did not. In the case of the South African students presented in this report, 1 769 students took a science subject while 482 students did not. The study was designed so that school leavers could be assessed as a whole in terms of their readiness to apply their mathematics and science knowledge in real life situations.

Figure 4.1 presents the students' average score achieved in this test. South Africa is compared here to 10 other countries. As highlighted in the International report, South Africa obtained a significantly lower average score (352 points) than the other participating countries for which the international average score was 500 on a scale of 800 points.

Figure 4.1: South African students' average mathematics and sciences literacy score in comparison with other countries

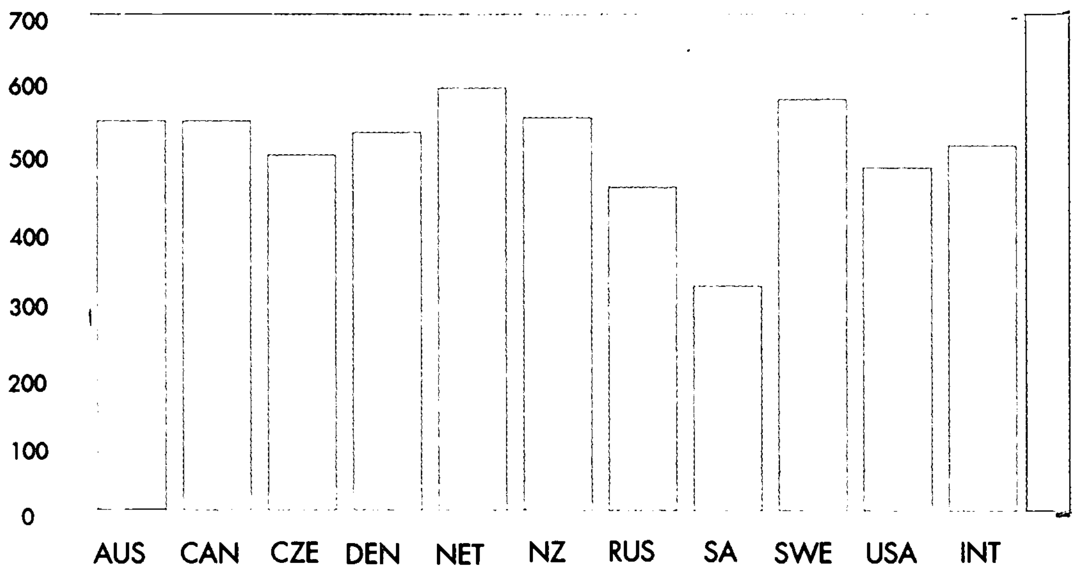


17 This included mathematics, physical science, biology and geography on either standard grade or higher grade.

4.2 The comparative performance of the top 25 % of South African students

Figure 4.2 below represents the average achievement of the top 25 % of the students in the entire school-leaving age cohort for South Africa and ten other countries. Here South African students' performance was also lower than that of the other participating countries, achieving 328 points compared to the International average of 520 points.

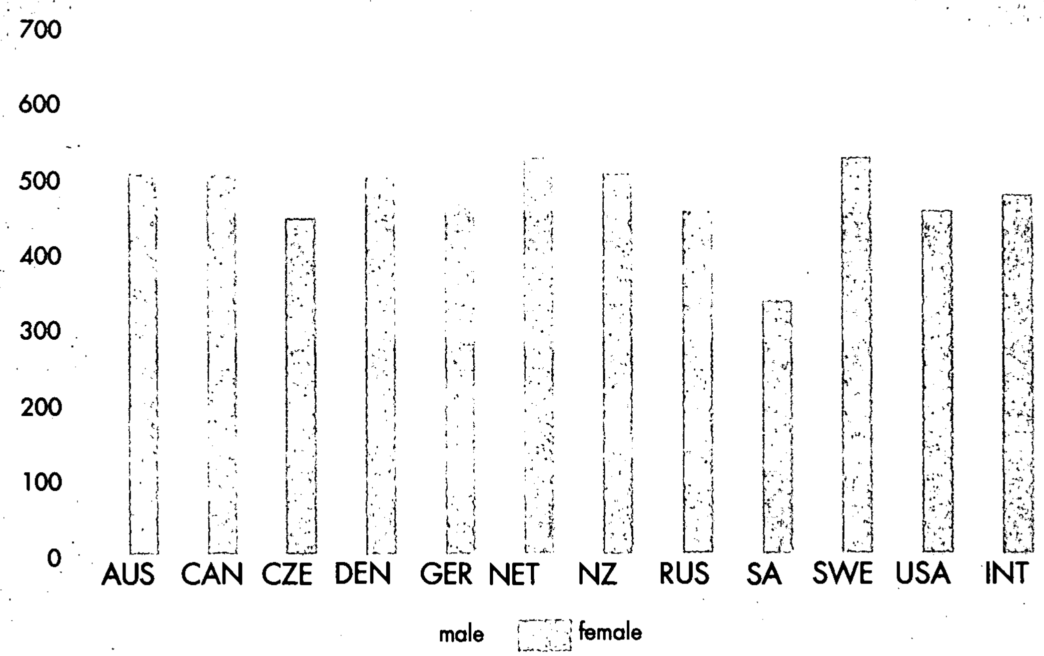
Figure 4.2: Comparative performance of the top 25% of South African students (average scores)



4.3 The comparative performance of South African students by gender

Figure 4.3 shows the differences in the students' achievement by gender. Internationally, the male students performed significantly better than the female students, achieving 519 compared to 483 pints respectively. This was not the case in South Africa where there was no significant difference (males 366, females 341). This was also the case in the TIMSS results for South African Grade 7 and Grade 8 students.

Figure 4.3: Comparative performance of South African students by gender (average scores)



4.4 Students' performance compared per province

The results for the provinces were significantly different in some cases. As can be seen from Table 4.1 below, the provinces that performed above the South African national average score were Free State, Gauteng, KwaZulu-Natal, Northern Cape and Western Cape. The Northern Cape and Western Cape scored well above the national average of 352 points (and the Western Cape students' average was well above the international average of 500 points).[18]

The remaining provinces scored below the national average (i.e. Mpumalanga, Northern Province, North West and Eastern Cape). The results of this group, with the possible exception of the North West Province, are not surprising considering the current conditions in education in these provinces.

Despite some of the low scores that were achieved, there were also exceptionally high scores obtained. It is encouraging to note that the maximum scores of students in the Free State (593), Gauteng (642), KwaZulu-Natal (700), Northern Cape (502) and Western Cape (761) were above the international average (500). In the case of students in KwaZulu-Natal and the Western Cape, exceptionally high scores were achieved. Further research will be conducted to investigate the reasons for these very good results as well as the poor results achieved by students in the rest of South Africa.

18 Due to the small size of the samples in both of these provinces, these results cannot be considered representative.

Table 4.1: Students' achievement per province[19]

Province	Average score obtained	Minimum score	Maximum score
Eastern Cape	315	195	422
Free State	409	229	593
Gauteng	370	236	642
Kwazulu-Natal	395	206	700
Mpumlanga	342	194	583
Northern Province	305	165,5	487
North-West	321	223	434

4.5 Students with a science subject compared to students with no science subject

As the sample of students who were tested also included students who did not take any science subject at all, it was possible to compare those students' literacy levels with students who had taken at least one science subject for matriculation (Grade 12). Students were asked to indicate which of the following subject choices they were taking:

- Mathematics (higher grade) and physical science (higher grade)
- Mathematics (standard grade) and physical science (higher grade)
- Mathematics (higher grade) and physical science (standard grade)
- Mathematics (higher grade) and no physical science
- Mathematics (standard grade) and physical science (standard grade)
- No mathematics and no physical science

19 The figures for the remaining provinces are shown below in the same format as Table 4.1

Northern Cape	*458*	*409*	*502*
Western Cape	*618*	*468*	*761*

The results of the performance of these different groups are presented below:

Table 4.2: South African students' performance per subject option

Subject option	Average score	minimum score	maximum score
Mathematics (higher grade) and Physical science (higher grade)	397	215	761
Mathematics (standard grade) and Physical science (higher grade)	353	195	643
Mathematics (higher grade) and Physical science (standard grade)	334	203	680
Mathematics (higher grade) and no Physical science	332	194	640
Mathematics (standard grade) and Physical science (standard grade)	380	200	623
No mathematics and no Physical science	320	223	511
Overall National Score	352		

As expected, the average scores indicated that the students taking the option of higher grade mathematics and higher grade science achieved the highest results; and the students not taking either mathematics or science achieved the poorest results. However, on closer analysis, a number of oddities emerge. The average score of those doing no mathematics and science compared to that of students taking mathematics with physical science (standard grade) or without physical science, shows a very small differential (12-14 points). This raises questions about the value of doing either formal mathematics or physical science in relation to impacting on literacy in these subjects. Interestingly, the lowest scores were attained by students who were in fact taking both mathematics and physical science. Another surprising observation was the fact that students taking mathematics and science on standard grade performed better than students taking standard grade mathematics and higher grade science. All in all, the fact that little value is added to students' general scientific literacy by enrolling for an additional mathematics or science subject is testimony to the poverty of our current system.

4.6 Students' performance related to their use of the language of instruction

Students were tested in their language of instruction, which in 1995 was either English or Afrikaans. Students were asked to indicate the degree to which they spoke the language of instruction at home. From these responses, Table 4.3 was compiled, indicating whether or not students spoke the language of instruction at home always, sometimes or never. It would appear from the average scores that the students who did speak the language of instruction as their home language performed significantly better overall than those students who either did not speak the language of instruction at home or sometimes did. As this difference can be attributed to a number of reasons (e.g. students speaking English/Afrikaans at home may also have come from better socio-economic backgrounds), there is no simplistic way to explain this. Despite this result, there were students in the groups who never spoke the language of instruction at home, and some who sometimes did, who achieved exceptionally high results that were well above the international average. The whole question of language and performance will be analysed in detail through further research.

Table 4.3: Students' performance compared to their use of the language of instruction

Students use of language of instruction at home	Number of students	Average score obtained
always	502	442
sometimes	1 913	317
never	251	318,5

4.7 Conclusion

Although the South African students did not perform well overall, there were individual students who did excel and achieved very high scores. It also encouraging to note that there was no significant difference between the boys and girls in terms of their mathematics and science literacy scores. It was also interesting to see the difference in the students' scores between the provinces and policy-makers will find these results of particular interest.

Chapter 5

Achievement in mathematics literacy and science literacy

Key points

- South African students performed significantly worse overall in the mathematics and science literacy test.
- South African students performed marginally better in mathematics than science.
- There was no significant difference in the performance of boys and girls in either mathematics or science.
- Students in the KwaZulu-Natal and the Free State provinces performed above the national average for mathematics and science.

Chapter 5

Achievement in mathematics literacy and science literacy

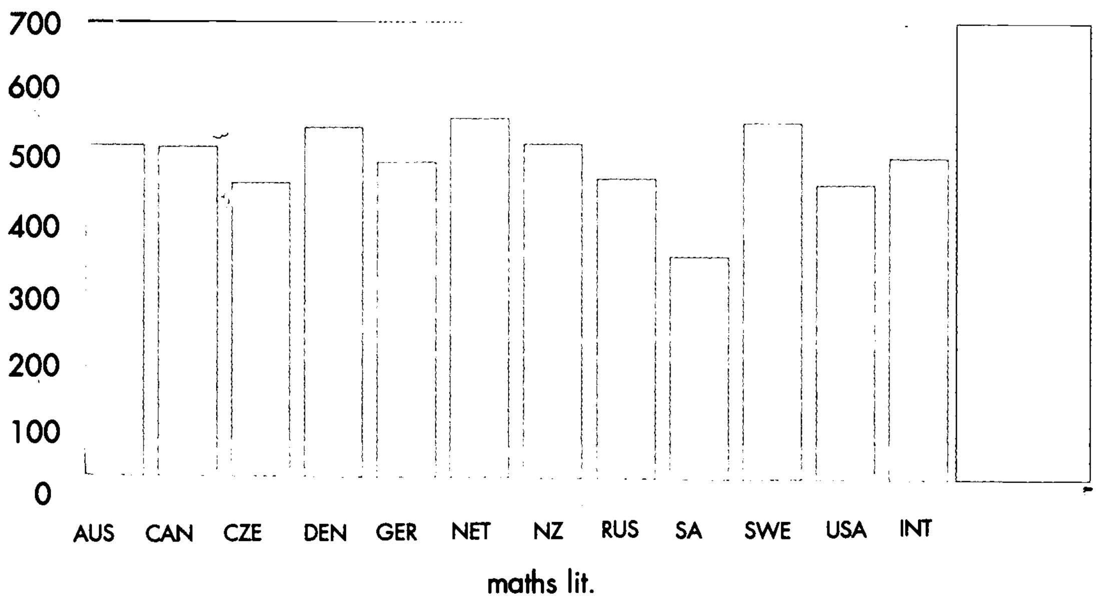
This chapter focuses on students' performance in the areas of mathematics literacy and science literacy, separately, and discusses the results by gender, province and language.

5.1 Performance of South African students in mathematics literacy

The mathematics literacy test items included number sense (including fractions, percentages and proportionality), algebraic sense, measurement and estimation, data representation and analysis. Reasoning and social utility were emphasised in several items. Mathematics questions were intended to be relevant to real life situations.

The figure below presents the results of the South African students compared to 10 other countries. A number of countries, including Denmark, performed significantly better in mathematics than in science. The South African students performed marginally better in the mathematics literacy items than they did in the science literacy items, achieving a score of 356 points compared to the international average of 500 points.

Figure 5.1: Comparative performance of South African students in mathematics literacy



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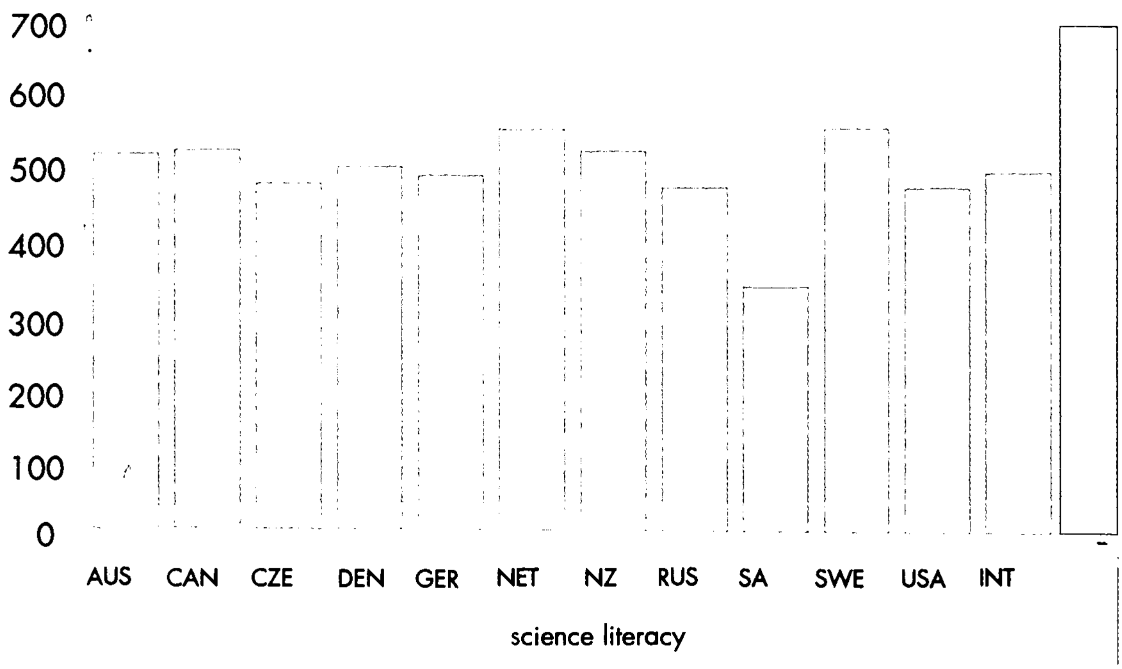
5.2 Performance of South African students in science literacy

The science items included the areas of earth science, life science and physical science. The items also included a reasoning and social utility component. The use of calculators was permitted for this test. The Figure 5.2 below presents the results of the South Africa students compared to 10 other countries. Several countries, including Sweden, the Russian Federation, the Czech Republic, Canada and the USA, performed significantly better in the science literacy items than the mathematics. South African students' performance was, again, lower than that of all the other participating countries, achieving a score of 349 points compared to the international average of 500 points.

Figure 5.2: Comparative performance of South African students in science literacy



5.3 South African students' comparative performance in mathematics and science literacy by gender

There were significant differences between the performances of male and female students internationally in both mathematics and science. However, in science there was a greater difference than in mathematics. This was true for all countries except South Africa, where there was no significant difference in either mathematics or science.

Figure 5.3: South African students' comparative performance in mathematics literacy by gender

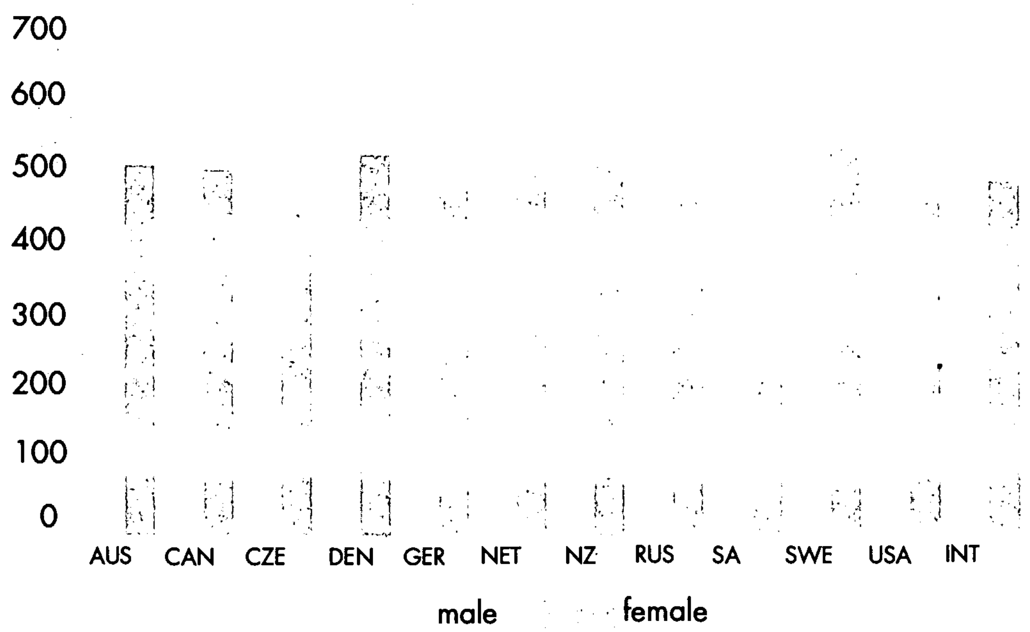
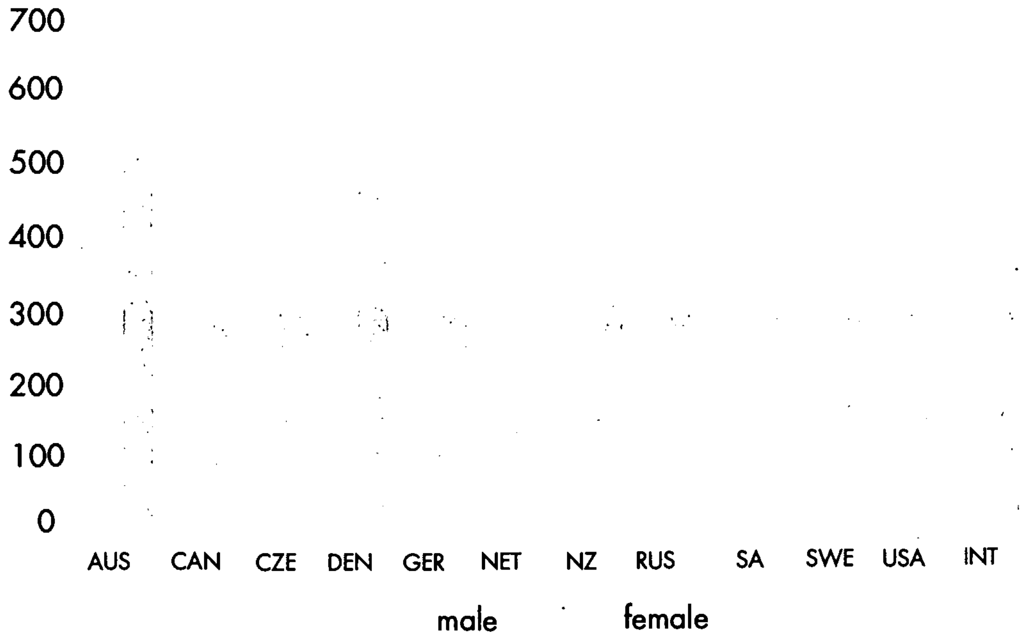


Figure 5.4: South African student's comparative performance in science literacy by gender



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5.4 The performance of South African students, by province, in mathematics literacy and science literacy

The performance of the South African students varied considerably across the different provinces. In Table 5.1 below the students' scores by province and subject are presented. In the mathematics literacy items, the students in the Eastern Cape, Mpumalanga, Northern and North West provinces performed below the national average. The students in KwaZulu-Natal and the Free State province performed well above the national average. Although the scores for the Northern Cape and especially the Western Cape appeared to be well above the national average, these scores (as mentioned previously) cannot be seen to be representative due to the very small size of both these samples.

In the science literacy items, as with the mathematics literacy items, students from the Eastern Cape, Mpumalanga, Northern Province and the North West Province performed below the national average. Once again, the students from KwaZulu-Natal and the Free State performed well above the national average.

Table 5.1: Comparative provincial scores per subject

Province[20]	Maths and science literacy average score	Mathematics literacy average score	Science literacy average score
Eastern Cape	316	322	310,5
Free State	410	397	423
Gauteng	378	328	374
Kwazulu-Natal	404	403	405
Mpumalanga	346	349,5	342
Northern Province	308	316	300
North West	319	325	312
South Africa	352	356	349

20 The scores for the Northern Cape and Western Cape scores cannot be considered representative and therefore are not included in Table 5.1 and are presented below:

Northern Cape	*457.5*	*439*	*476*
Western Cape	*618*	*612*	*624*

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5.5 South African students' performance in mathematics literacy and science literacy, by language of instruction used

The students were asked to state the extent to which they spoke the language of the test (which was the language of instruction at their school) at home, (i.e. always, sometimes or never). The results are presented in Table 5.2, by province and by language of instruction.

There are several surprising results from this analysis. First, there seemed to be a difference between the students using the language of the test in four out of the nine provinces, namely Free State, Gauteng, KwaZulu-Natal and Mpumlanga. In three of these provinces, namely Free State, Gauteng and KwaZulu-Natal, the students' overall scores, science literacy scores and mathematics scores were better than the other provinces. Based on the average scores, the students from the Western Cape and the Northern Cape, although their scores were not representative of the province, had scores that were well above the national average and did not seem to follow the same pattern as the Free State, Gauteng, KwaZulu-Natal and Mpumlanga scores. In the Western Cape and Northern Cape the findings suggest that students did not appear to be disadvantaged by the language of the test. For instance, the students in the Northern Cape who *sometimes* spoke the language of the test had better scores in both the mathematics literacy and science literacy than the students who *always* spoke the language at home. In the Western Cape, students who never spoke the language at home achieved higher scores than those who always spoke the language at home. These unexpected findings will need investigation.

In the Northern Province, the Eastern Cape and North West Province, the situation appears to be more complex. There was no relation between the students use of language at home and their performance in either mathematics or science. In fact, the scores were poor across all three provinces and across the three groups of language use at home. This suggests that there appears to have been serious inadequacy in the learning and teaching of science and mathematics, which is pervasive throughout these students' school careers in these provinces. The low levels of literacy in mathematics and science should be alarming to the policy makers in these provinces, especially in the Eastern Cape and Northern Province which also have the highest unemployment figures in the country.

The relationship between language and performance in mathematics and science is an issue that will be investigated as a project on its own as it is perceived to be not only a complex question, but also a critical issue.

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Table 5.2 The performance of students by their use of the language of the test

Province[21]	Use of language of instruction	Mathematics average literacy score	Science average literacy score
Eastern Cape	always	315	319
	sometimes	323	310
	never	315	303
Free State	always	436	482
	sometimes	324	320
	never	334,5	320,5
Gauteng	always	463	471
	sometimes	342	327
	never	361	333
Kwazulu-Natal	always	451	464
	sometimes	331	317
	never	319	306
Mpumalanga	always	441	466
	sometimes	317	299
	never	323	302
Northern	always	316	307
	sometimes	314	292
	never	321	308
North West	always	337	336
	sometimes	325	309
	never	337	312

21 The Northern Cape and Western Cape Province were not included in Table 5.2 as these scores were not representative due to the small size of the sample. These provinces'scores are presented below:

Northern Cape	*always*	*434.5*	*473*
	sometimes	*447*	*484*
Western Cape	*always*	*622*	*628*
	sometimes	*541*	*592*
	never	*617*	*636*

5.6 Conclusion

This chapter provided a breakdown of the mathematics literacy scores and the science literacy scores, and examined the factors involved. Much more research will need to be conducted to investigate issues raised in this chapter, particularly with reference to the provincial analysis and the reasons why South African students performed better in mathematics literacy than in science literacy.

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Chapter 6

Performance on mathematics and science literacy items

Key points

- On all the items presented the performance of South African students was the lowest.
- South African students appear to have difficulty with graphic interpretation.
- In general South African students experienced great difficulty in articulating explanations for the free-response items.

Chapter 6

Performance on mathematics and science literacy items

6.1 Preamble

Apart from the overall achievement results and an understanding of how students performed in the broad content areas, it is also useful to examine students' performance on specific items. This chapter explores performance in four example items within both the mathematics and science literacy content areas. Although the selection of these items attempted to include as broad a range of topics as possible, this was limited due to the few items examined.

The literacy test was designed to test students' general mathematical and scientific knowledge. The items were selected on the basis that they reflected questions that relate to real life situations.

Three types of questions were included in the literacy test - multiple-choice, short answer and extended response items. The two latter types of questions expected students to generate and articulate their own responses. Scoring of free-response items rested on whether the response was completely or only partially correct. Two to three marks were awarded for a fully correct response. For the multiple- choice questions most questions were worth one point. The table below indicates the weighting for the different types of questions within the literacy test.

Table 6.1: Distribution of mathematics and science literacy items by reporting category

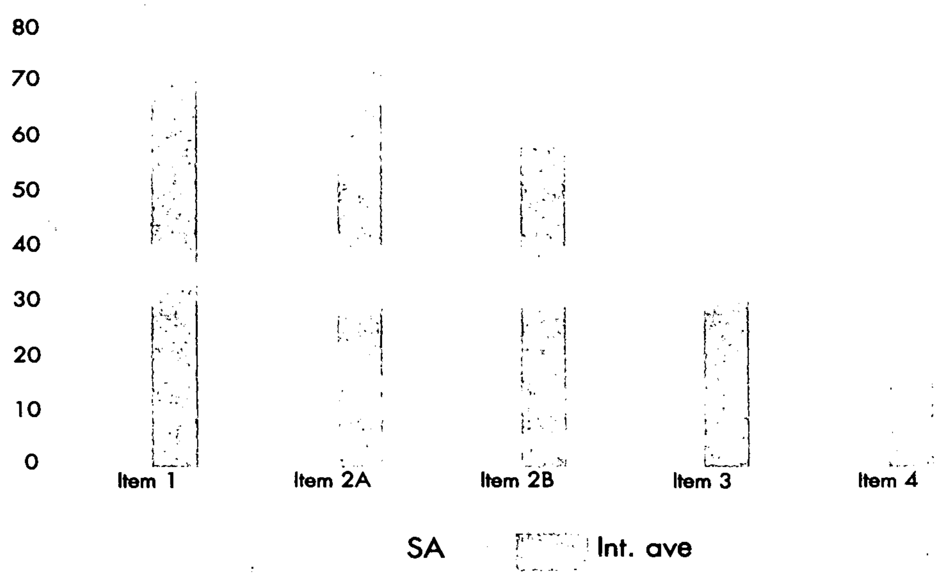
Content category	% of items	Number of items	Number of multiple choice items	Number of short answer items	Number of extended response items	Number of score points
Mathematics literacy	58 %	44	34	8	2	53
Science literacy	42 %	32	18	9	5	43
TOTAL	100 %	76	52	17	7	96

(Mullis, 1998:B-9)

6.2 Example items in mathematics literacy

In general the items within the mathematics literacy content area were designed to define adequately the content area and restrict the items to the content areas most closely related to mathematical literacy. In this chapter items relating to number sense, data representation and estimation are included to illustrate the types of questions appearing in the literacy tests and the performance attained on these items. Some items reflect the reasoning skills expected of students. The items emphasise the types of understanding and skills needed for effective participation in today's information-rich society. Figure 6.1 illustrates the comparison between the South African scores and the international averages for the mathematics example items.

Figure 6.1: Comparison between SA scores[22] and the international averages for the mathematics example items



Example Item 1:

If there are 300 calories in 100 grams of a certain food, how many calories are there in a 30 gram portion of that food?

A. 90

B. 100

C. 900

D. 1000

This question is a straightforward proportionality problem, which receives significant attention within the South African curriculum, at least by Grade 9. Most countries fared reasonably well on this item. The average percentage of correct answers across the participating countries was 71 %, with scores ranging from 45-84 %. South Africa performed well below the international average at 45 %. Table 6.2 gives a comparison of South African students' performance on this item with some other countries.

22 Only fully correct responses are indicated on the graph.

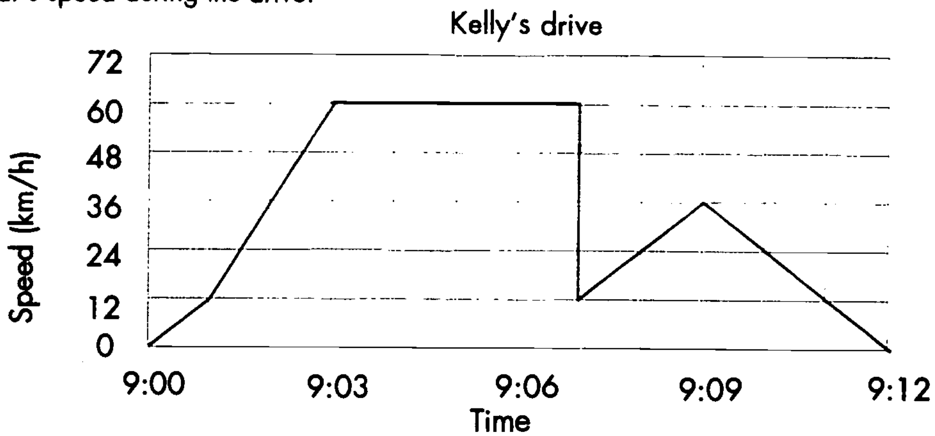
Table 6.2: Mathematics literacy: percent correct for example item 1

Country	Percent correct
Australia	79
Canada	73
Czech Republic	61
Denmark	75
Germany	74
Netherlands	84
New Zealand	75
Russian Federation	71
Sweden	74
USA	68
South Africa	45
International average percent correct	*71*

Example Item 2:

Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat.

Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.



(a) What was the maximum speed of the car during the drive? ....

(b) What time was it when Kelly slammed on the brakes to avoid the cat?
....

In this item students were expected to interpret a graph and then to provide responses to the questions. In the first part they needed to be able to read a line graph and use the axes information to determine the maximum speed. The international average of correct responses was 74 %, whereas in South Africa 60 % of students responded correctly. These scores indicate that students found this part of the question relatively easy. The second part of the problem which involved further interpretation of the information in the graph proved to be more difficult for students. Whereas the international average was 59 %, only 19 % of South African students got the answer correct. This could imply that South African students have difficulty in understanding graphs, particularly the seemingly more complex sections where the graph line descends. The range of correct responses internationally was 19-83 %.

Table 6.3: Mathematics literacy: percent correct for example Item 2

Country	Percent correct (part A)	Percent correct (part B)
Australia	88	68
Canada	80	67
Czech Republic	66	47
Denmark	78	67
Germany	74	62
Netherlands	91	83
New Zealand	91	74
Russian Federation	62	46
Sweden	85	69
USA	85	67
South Africa	60	19
International average percent correct	*74*	*59*

Example Item 3:

Brighto soap powder is packed in cube-shaped cartons. A carton measures 10 cm on each side. The company decides to increase the length of each edge of the carton by 10 per cent. How much does the volume increase?

A. 10 cm^3

B. 21 cm^3

C. 100 cm^3

D. 331 cm^3

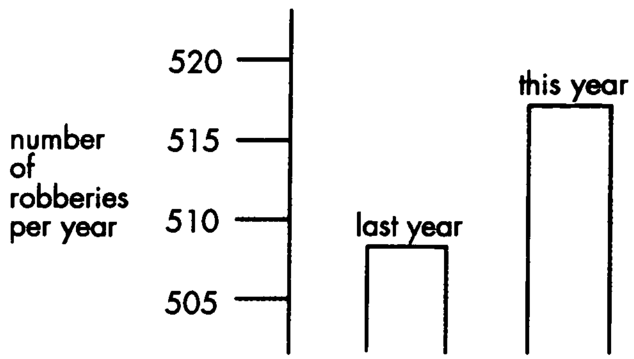
This problem involves percentages and volume, and requires a number of steps to solve. From the results it can be assumed that the students found this a difficult problem. Fewer than half of the students selected the correct solution in each of the participating countries. In South Africa only 6 % of the students selected the correct answer and the international average at 31 % is also very low. Difficulties with this item could be linked to the complexities of multi-stepped approaches to solving problems, the calculation of percentages or the concept of volume.

Table 6.4: Mathematics literacy: percent correct for example Item 3

Country	Percent correct
Australia	30
Canada	29
Czech Republic	21
Denmark	41
Germany	25
Netherlands	50
New Zealand	36
Russian Federation	30
Sweden	41
USA	17
South Africa	6
International average percent correct	*31*

Example item 4:

A TV reporter showed this graph and said: "There's been a huge increase in the number of robberies this year".



Do you consider the reporter's statement to be a reasonable interpretation of the graph? Briefly explain.

This item is an open-ended question asking students to comment on a reporter's interpretation of a graph. On average, 19 % of the students across countries received full credit for their responses. Another 26 % received partial credit[23] for their responses. Of the items presented in this chapter the performance scores for this item are the lowest. The international average for fully correct answers was 19 % and the average for South Africa was 3 %. Clearly students in general found this type of open-ended, free-response item problematic, and had difficulty in articulating responses.

Table 6.5: Mathematics literacy: percent correct for example item 4

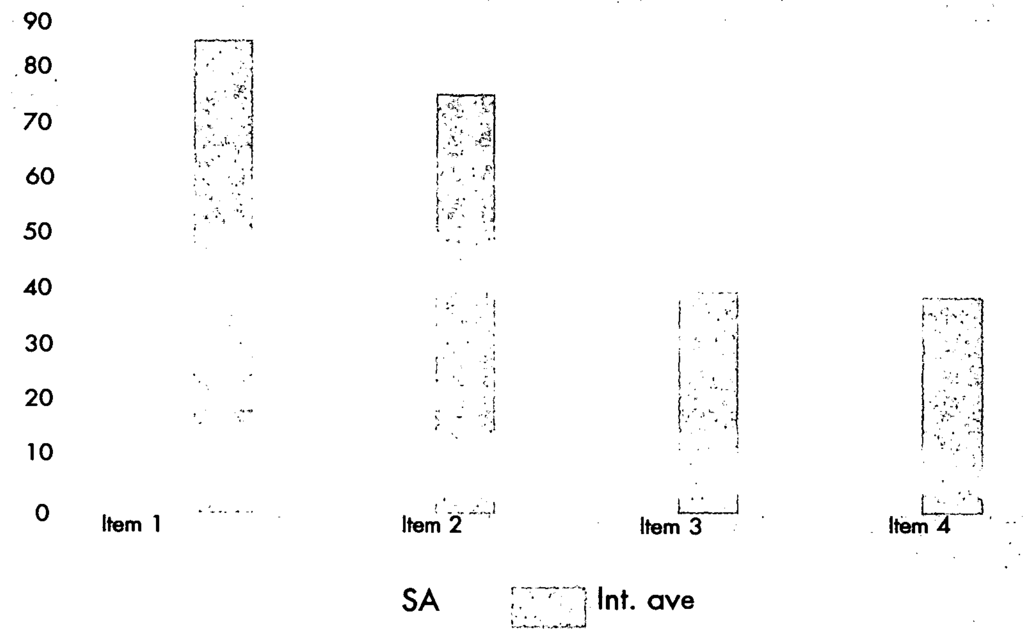
Country	Percent partially correct	Percent fully correct
Australia	39	26
Canada	35	23
Czech Republic	26	6
Denmark	25	26
Germany	26	20
Netherlands	27	30
New Zealand	38	33
Russian Federation	13	7
Sweden	29	37
USA	41	14
South Africa	12	3
International average percent correct	*26*	*19*

6.3 Performance on science literacy

The science literacy content areas covered earth science, physical science (energy and other physical science) and life science (human biology and other life science). The emphasis in testing in this section of the literacy test embraced how students could use their knowledge in response to science-related problems. Figure 6.1 illustrates the South African scores for the 4 example items compared to the international averages.

23 Free-response items were coded according to whether they were entirely correct, partially correct or incorrect.

Figure 6.2: Comparison between SA scores[24] and the international averages for the science example items



Example Item 1:

It is often claimed that "cooked vegetables are not as nutritious as the same kinds of vegetables uncooked". What could be done to find out if this statement is true?

A. Compare the weight of the vegetables before and after they are cooked.

B. Compare the colour of the cooked and uncooked vegetables.

C. Test the acidity of the water in which the vegetables are cooked.

D. Compare the vitamin content of the cooked and uncooked vegetables.

This item required an understanding of the links between vitamin content and nutrition. It was one of the easier items in the science section. The international average of correct responses was 87 % and the proportion of students selecting the correct answer in South Africa was 55 %. The South African score was significantly lower than those of all the participating countries, of which the next lowest score was 81 %.

24 Only fully correct scores are indicated on the graph.

Table 6.6: Science literacy: percent correct for example Item 1

Country	Percent correct
Australia	89
Canada	91
Czech Republic	92
Denmark	93
Germany	87
Netherlands	89
New Zealand	86
Russian Federation	88
Sweden	90
USA	81
South Africa	55
International average percent correct	*87*

Example item 2:

CFC's (chlorofluorocarbons) revolutionised personal and industrial life for 30 years. They were in refrigerators and the propellants in aerosols, pressure packs and fire extinguishers. There are now very strong international moves to stop the use of these substances because

A. they are chemically inert

B. they contribute to the greenhouse effect

C. they are poisonous to humans

D. they destroy the ozone layer.

This item focused on the issue of chlorofluorocarbons polluting the atmosphere. Again this question was answered correctly by a large proportion of students in all the participating countries with the international average percent correct at 77 %. However, a low proportion of South African students (39 %) obtained the correct solution.

Table 6.7: Science literacy: percent correct for example Item 2

Country	Percent correct
Australia	69
Canada	84
Czech Republic	92
Denmark	83
Germany	66
Netherlands	89
New Zealand	79
Russian Federation	66
Sweden	93
USA	77
South Africa	39
International average percent correct	*77*

Example Item 3:

Some high heeled shoes are claimed to damage floors. The base diameter of these very high heels is about 0.5 cm and of ordinary heels about 3 cm.

Briefly explain why the very high heels may cause damage to floors.

As this was a free-response item students received credit for partially correct answers. The international average for partially correct answers was 20 % and for fully correct answers 41 %. South Africa had 9 % providing partially correct answers and 10 % offering fully correct answers.

Table 6.8: Science literacy: percent correct for example Item 3

Country	Percent partially correct	Percent fully correct
Australia	17	53
Canada	18	51
Czech Republic	22	28
Denmark	25	39
Germany	13	52
Netherlands	23	55
New Zealand	23	45
Russian Federation	22	31
Sweden	24	47
USA	18	24
South Africa	9	10
International average percent correct	*20*	*41*

Example Item 4:

Nuclear energy can be generated by fission or fusion. Fusion is not currently being used in reactors as an energy source. Why is this so?

A. The scientific principles on which fusion is based are not yet known.

B. The technological processes for using fusion safely are not yet developed.

C. The necessary raw materials are not readily available.

D. Waste products from the fusion process are too dangerous.

The achievement scores on this item ranged from 26-51 %. As such the scores on this item were not particularly high. The international average percent correct was 40 % and 26 % of South African students selected the correct solution.

Table 6.9: Science literacy: percent correct for example item 4

Country	Percent correct
Australia	42
Canada	40
Czech Republic	38
Denmark	51
Germany	44
Netherlands	41
New Zealand	37
Russian Federation	50
Sweden	54
USA	41
South Africa	26
International average percent correct	*40*

6.4 Conclusion

On all the items discussed, the performance of South African students was the lowest among the participating countries. South African students do not appear to perform very well in the area of graphic interpretation. Their performance in multiple-choice questions seems to be a function of the level of difficulty or complexity of the item. In general, South African students also experienced great difficulty in articulating explanations for the free-response items. More in-depth analysis concerning how students do on multiple-choice questions as opposed to free-response items, and their responses to the test items, is likely to uncover some of the misconceptions held by the students, and areas of difficulty they experience.

Conclusion

International comparative studies provide a broad understanding of different educational systems. Of immense benefit derived from these kinds of studies is the insight obtained concerning the curricula followed in various countries, the contexts supporting the learning of these curricula and the performance of students as a result of being exposed to particular curricula. In the past, the findings of international comparative studies and their subsequent policy recommendations have catalysed various countries to introduce educational reforms. In South Africa, this study starts to address the dearth of national data concerning mathematics and science education. The results of TIMSS thus constitute useful baseline information which can inform educational planning for the next few years.

The overall results for final-year students taking the mathematics and science literacy test are somewhat bleak. The fact that South African students performed so poorly in the test, as well as on individual items, suggests that their general mathematics and science understanding and skills are limited, falling short of literacy levels necessary for effective functioning in society. TIMSS provides policy makers and practitioners with the *status quo* in mathematics and science competencies. Definite benefits are to be gained from monitoring the progress of these competencies within a longitudinal study (every 3 years). It would be particularly useful to establish the impact of "Curriculum 2005" in terms of improving the types of skills that were tested in the TIMSS literacy test. Such insight can serve to aid the government in the assessment of its current policy initiatives.

From the preliminary TIMSS analysis, a number of issues have already emerged which beg either secondary analysis or further research. The issue of taking word-problem-oriented tests in a second or third language should be examined, to establish the extent to which this impacts on performance levels. The question of why a considerable amount of time spent on homework can add very little value to performance levels in mathematics and science literacy needs exploration. Students *taking* mathematics and science did not perform a lot better than those *not taking* these subjects. Does this imply that formal schooling in these subjects does not prepare young people with the numerical and scientific literacy needed for the world of work (or even tertiary studies)? More in-depth analysis of how students do on multiple-choice items as opposed to free-response items is likely to provide insight in terms of the misconceptions held, and areas of difficulty faced by the students. This can serve to inform both curriculum and textbook developers, as well as educational practitioners. Finally, the dominant factors impacting on performance levels in mathematics and science literacy in South Africa could be delineated. There is a host of information linked to this that can be uncovered at provincial level.

If South Africa is to succeed as a country in a rapidly changing competitive world in which science, engineering and technology are becoming increasingly important, a premium must be placed on science and technology education. The development of human resources in these fields is of utmost importance. This study is useful as a frame of reference for monitoring purposes when programmes, reforms and other educational initiatives linked to mathematics and science education are implemented. The TIMSS study in South Africa provides the necessary information to contribute to finding solutions to the educational challenges that plague our country at present.

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