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MATHEMATICS AND SCIENCE IN SOUTH AFRICA: AN INTERNATIONAL ACHIEVEMENT STUDY AT JUNIOR SECONDARY LEVEL

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MATHEMATICS AND SCIENCE IN SOUTH AFRICA: AN INTERNATIONAL ACHIEVEMENT STUDY AT JUNIOR SECONDARY LEVEL

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If it can be measured - it's Science, all else is opinion.

Robert Heinlein

Statistics are the triumph of the quantitative method,
and the quantitative is the victory of sterility and death.

Hilaire Belloc

KEYWORDS

Achievement	Assessment	Curriculum analysis
International Association for the Evaluation of Educational Achievement		
IEA	Junior secondary	Mathematics education
Science education	Textbook analysis	Theories of learning
Third International Mathematics and Science Study [TIMSS]		

SUMMARY

The Third International Mathematics and Science Study is the largest international study of its type undertaken. Over 500 000 students in Grades 7 and 8 (Standards 5 and 6) from forty-two countries participated in the programme. The South African sample involved 9 887 students. The ranking order shows that South Africa was placed last out of the forty-two countries ranked. This included only three other developing nations: Colombia, Iran and Thailand. South Africa was the only African country that participated in TIMSS; and this study was designed to investigate and evaluate South Africa's achievements in Mathematics and Science at the Junior Secondary level through the TIMSS testing instruments.

Chapter 1 suggests reasons for and the likely benefits from participation in international studies of this nature. Chapter 2 outlines relevant theories of learning and the opportunities to apply them to South African Mathematics and Science education and so provides a background for examining the test findings.

Chapter 3 considers the contexts within which the South African study took place and describes the educational 'climate' in which the testing programme occurred. The fact that TIMSS - South Africa took place amidst all the uncertainties of restructuring eighteen different education departments into nine provincial departments is highlighted. The technical design, data processing and methodology of TIMSS are set out in Chapter 4.

Chapter 5 comprises a comparative analysis of South African performance in specific groups of Mathematics and Science questions with those of the other participating developing nations and selected developed nations in order to provide as broad a perspective as possible. Important findings are that the

South African students displayed poor competency in concept formation and thinking skills in Mathematics and Science and were weak in fundamental processes and awareness of number sense, particularly in Mathematics. In the Natural Sciences there a corresponding lack of problem solving abilities was displayed. Although the South African Science curriculum was shown to be appreciably 'out of step' both with the curricula of other participating countries this had little impact on the eventual achievement levels.

Chapter 6 examines the profile of participating South African students in terms of their home and school milieux, attitudes towards Mathematics and Science learning and teaching and language of instruction. It is significant that with the exception of Colombia, South Africa had the oldest participating group; and South African students are allocated a minimum of scheduled time for these subjects compared to most other nations.

The concluding chapter reviews the aims, objectives and premises of this study and makes recommendations summarises identified problems. In particular, a synopsis of the impact of second language instruction on learning and the 'time on task' problem in Mathematics and Science is given. The findings are particularly relevant since they present a 'first ever' national picture and international comparison of Mathematics and Science achievement in South Africa at Junior Secondary level.

OPSOMMING

Die Derde International Wiskunde en Wetenskap Studie (TIMSS) is die grootste internasionale studie van hierdie aard wat tot dusver onderneem is. Meer as 500 000 studente in Grade 7 en 8 (Standerds 5 en 6) van twee en veertig lande het aan hierdie program deelgeneem. In Suid-Afrika was 9987 leerlings betrokke by die navorsing. Die rangorde volgens die TIMSS toets toon dat Suid-Afrika die laagste van die twee en veertig gerangde lande presteer het. TIMSS het slegs drie ander onwikkelende lande ingesluit: Colombia, Iran en Thailand. Suid-Afrika was die enigste staat in Afrika wat aan TIMSS deelgeneem het. Hierdie studie is beplan om Suid-Afrika se prestasies in Wiskunde en Natuurwetenskap op die Junior Sekondêre vlak deur die TIMSS toetsinstrumente te ondersoek, en te evalueer en ook met ander lande te vergelyk.

Hoofstuk 1 behandel redes vir en die moontlike voordele van deelname aan internasionale studies van hierdie aard. Hoofstuk 2 behandel relevante leerteoretiese uitgangspunte in natuurwetenskap- en wiskunde-onderwys. Dit verskaf die teoretiese onderbou waarteen die TIMSS data beoordeel kan word.

Hoofstuk 3 behandel die konteks waarin die Suid-Afrikaanse navorsing plaasgevind het en beskryf die opvoedkundige 'klimaat' waarbinne die toets-programme plaasgevind het. Die feit dat TIMSS in Suid-Afrika plaasgevind het te midde van die onsekerhede van die herstrukturering van agtien verskillende onderwysdepartemente tot nege provinsiale departemente word beklemtoon. Die tegniese beplanning, wyse van dataprosessering en metodologie van TIMSS word in hoofstuk 4 uiteengesit.

Hoofstuk 5 bevat 'n vergelykende analise van die Suid Afrikaanse prestasie in spesifieke groepe van vrae in Natuurwetenskap en Wiskunde. Die vergelyking

is gedoen tussen deelnemende ontwikkelende lande en geselekteerde ontwikkelde lande om 'n breë perspektief te gee. Belangrike afleidings uit hierdie analise is dat Suid-Afrikaanse studente openbaar 'n swak bekwaamheid in basiese begrippe en denkvaardighede in Natuurwetenskap enWiskunde. In samehang hiermee het leerders swak probleemoplossings-vaardighede vertoon. Die analise het verder getoon dat die Suid-Afrikaanse kurrikulum in Natuurwetenskap merkbaar uit pas is met die van ander deelnemende lande. Die navorsing toon ook dat die kurrikulum nie 'n betekenisvolle impak op leerlinge se prestasie in Wiskunde en Natuurwetenskap het nie.

Hoofstuk 6 ondersoek die profiel van deelnemende Suid-Afrikaanse studente in terme van hulle huis en skool *milieu* asook hulle houdings teenoor leer en taal van onderrig in Natuurwetenskap en Wiskunde. Dit is veelseggend dat, met die uitsondering van Colombia, Suid-Afrika die oudste deelnemende leerlinge gehad het. Verder is dit opmerklik dat in Suid-Afrikaanse skole die minimum geskeduleerde tyd vir Natuurwetenskap toegelaat word in vergelyking met die meeste ander lande.

Die laaste hoofstuk gee 'n oorsig van die oogmerke, doelwitte en vooronderstellings van hierdie studie en maak aanbevelings oor die geïdentifiseerde probleme. 'n Kort samevatting van die impak van onderrig en leer in die tweedetaal op leereffek en tyd aan taak in Natuurwetenskap en Wiskunde word uitteengesit. Die resultate van die navorsing gee 'n eerste volledige analise en klassifikasie van junior onderwys in Wiskunde en Natuurwetenskap in Suid-Afrika wat ook internasionaal vergelyk word met ander lande.

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CHAPTER 1

THE PROJECT: SOUTH AFRICAN MATHEMATICS AND SCIENCE: AN INTERNATIONAL ACHIEVEMENT STUDY

1.1 PROBLEMS, AIMS, OBJECTIVES AND METHODOLOGY OF THE RESEARCH

1.1.1 PREAMBLE

This research is based on the assumption that, however necessary, scientific theories, adequate funding and facilities to support the educational process are, in themselves, not sufficient to ensure the economic survival of a country. Economic survival and trained people are inextricably linked and this is particularly so in the case of the production of mathematicians and scientists in a developing country such as South Africa. In his discussion of South Africa's science policy, Pouris (1996: 270) draws attention to 'the writing on the wall' when he proposes that,

> South Africa appears to be losing the race in science.

A comparable assumption is that if South Africa is not to lose further ground in a world in which the natural sciences and technology are becoming increasingly competitive, it is crucial for policy makers to be apprised of the base upon which to build the superstructure; and the Third International Mathematics and Science Study [TIMSS] (1995) is one of a series of national initiatives - the White Paper on Science and Technology, the Foresight Programme (Ngubane, 1996: 6-10) and the First National Research and Technology Audit (Amuah, 1996: 279-280) being others - which seek to assess the realities of the South African situation. Pouris's paraphrase (1996: 270) of the Queen of Heart's comment in *Alice in*

Wonderland pertains to the difficulties inherent in the rapid growth in the fields of science and technology:

> ...we can say that "in science it takes all the running you can do to stay in the same place".

In this context and accepting the premise (Baker, 1996: 266) that,

> In practice, the potential of any system is realized when tested on particular tasks,

the present study endeavours, through TIMSS, to assess the strengths and weaknesses of South Africa's school Mathematics and Science education system.

Orton's truism (1992:1) that 'Educational issues are rarely clear cut' underlines the complexities of the project. All teachers, whether experienced or not, tend to ride their own hobby horses. Yet, for education to be sound and for outcomes to be predictable, a degree of objectivity is crucial and this is particularly true of education in the natural sciences. An individual teacher may hold very firm views on a particular issue in mathematical and/or scientific education but must, at the same time, accept that very different, even completely contrary, views may be held by a colleague in the same field of study. Examples are not hard to find. Seemingly insoluble issues are those such as: To what extent does modern technology (the use of calculators and computers, for instance) assist the learning process? Is interactive learning more effective than individual learning? Does practical work enhance learning? Should there be a symbiotic relation between text and context; in other words, is environment-based education the best answer? This latter question is one of the important related issues discussed in this thesis.

Another contentious issue is that of designing and implementing appropriate curricula and then testing the effectiveness thereof. This problem is, at once, one of the most fascinating and complex topics in education. And, as Duda (Mendel & Fu, 1970: 3) observes in a related context, '... the problems encountered range from the practical to the profound' whether the focus is on aims and application or, as in this present study, on assessment of achievement.

Before the Third International Mathematics and Science Study, South Africa had not participated in any previous international achievement studies in the fields of Mathematics and Science. These impartial, empirical studies are invaluable in that they provide a view of the educational outcomes that result from the national investment in education in these important fields of learning. Such studies are also potentially important because they may offer a prognosis of South Africa's future economic performance, given that educational standards correlate closely with national economic performance as a whole (Serageldin, 1995: Annex, 1-4). Elsewhere, Serageldin (1991: 148-149) makes the point succinctly:

> In the last three decades very considerable progress has been made in recognizing the importance of Human capital formation, meaning that investment in people is now seen to be a very high return investment, especially in developing societies. The entire mainstream paradigm of development has now been expanded to include investment in Human resources as an essential ingredient of developing strategy.

1.1.2 THE PROBLEM, AIMS, OBJECTIVES AND PREMISES

1.1.2.1 Statement of the problem

It is, historically, a well documented fact that the South African education system, whilst generating large numbers of graduates in the Humanities, does not supply the needs for scientifically and technologically trained manpower (cf. Meiring Naudé, 1965; HSRC, 1981; Pouris, 1989; Lombard, 1991; AS&TS, 1993). This problem is exacerbated by current emigration trends (Central Statistics Bureau, 1996: 1; *Sunday Times*, 29 September 1996: no page; *Pretoria News*, 26 November 1996: 9) which show no sign of abating.

This study takes its impetus from five interrelated problems:

- To date, there has been no clear, impartial view of the status of South African Mathematics and Science achievement.
- There have, hitherto, been no validated comparative studies of Mathematics and Science achievement between South Africa and either developed or developing countries.
- There is, as yet, no definitive examination of the status of South African Mathematics and Science curricula in relation to those of other countries.
- Measurement of achievement and precise identification of problems are required before any 'reconstruction' of Mathematics and Science education can be suggested, or before any serious modification should be attempted.
- The relevance and effectiveness of learning theories do not appear to be a sufficiently significant part of classroom practice in South Africa in developing concept formation and problem solving skills.

1.1.2.2 Aims

In addition to the intentions of the International Association for the Evaluation of Educational Achievement [IEA] and TIMSS outlined later in this chapter under the IEA Mission Statement and the TIMSS aims, the specific aims of this research investigation are:

- to obtain a realistic view of South African Mathematics and Science achievement in an international context compared with developed and developing countries;
- to select and interpret the profile of a large population of South African students and to examine how this profile relates to student achievement in a Mathematics and Science Study [TIMSS];
- to derive a prognosis for South Africa's future economic development as it may be influenced by the outcomes of the current education system;
- to identify, at a national level, the successes and weaknesses in teaching and learning Mathematics and Science; and
- to explore a variety of opportunities that exist to up-grade attainment levels in Mathematics and Science by examining where learning and teaching theories may be applied in the TIMSS findings.

1.1.2.3 Objectives

To make statistical analyses to investigate:

- A classification of the two hundred and eighty-six TIMSS questions (one hundred and fifty Mathematics and one hundred and thirty-five Science questions) into categories of expected performance;
- Performance in questions with similar content areas;
- An analysis of achievement in the sub-divisions of Mathematics and Science fields of study;
- The variation of achievement between Standard 5 [Grade 7] and Standard 6 [Grade 8] students;
- the TIMSS question papers in terms of curriculum 'fit' and expected skills and knowledge performance;
- The impact of second language on achievement;
- Gender differences in achievement.

The major findings of the IEA Studies that apply to Mathematics and Science education in South Africa are listed in some detail below since these findings form the 'test-bed' against which South African achievement is compared. These findings fall into two main categories, namely general findings and more specialist findings from two Mathematics and Science IEA Studies.

1.1.2.3 (a) Selected general findings from past IEA Studies (Keeves, 1994: 3-23) applicable to South African Mathematics and Science achievements at Junior Secondary level

- **Research Finding 1** There are marked differences in average levels of achievement between the students in school in the More Developed Countries [MDC] and those in the Less Developed Countries [LDC]. This occurs in spite of the fact that in the Less Developed Countries significantly fewer than 100% of the relevant age groups are enroled at school.
- **Research Finding 4** Student achievement in Mathematics and Science is directly related to the instructional time given to these subjects.
- **Research Finding 5** After all other factors relating to achievement have been taken into account, achievement is related to the amount of time spent on homework (and other extramural Mathematical and Scientific activity.)
- **Research Finding 6** Achievement is related to opportunities to learn. The content and skills considered important for students to learn must be identified by curriculum developers, and students MUST be provided with appropriate opportunities to learn those content and skill attributes. It is important to note that the less developed the education system, the greater the care that should go into curriculum planning.

- Research Finding 8 The level of reading materials in the home correlates significantly with achievement. It appears that general opportunities to read assist the student in learning more specialized material.
- Research Finding 9 Socio-economic status correlates positively with achievement.
- Research Finding 11 There is a significant difference between achievement based on gender.

1.1.2.3 (b) Findings from Specialist IEA Studies

- Research Finding from Study 3 The First IEA Science Study

  There was no clear evidence to show that the extent of the students' practical experience was related to a higher level of achievement in science as measured against more theoretical tests (Comber and Keeves, 1973: 212; Walker, 1976: 98).
- Research Finding from Study 11 The Second Science Study

  The general level of experience, scientific training and interest of the teachers in science influenced the level of achievement of their students (Keeves, 1992: 204 and 224).

1.1.2.4 Fundamental premises that will be explored

This thesis seeks to explore four suppositions:

- that the South African education system is not educating students in Mathematics and Science to the achievement standards of other developing countries that participated in TIMSS;
- that a number of the findings of previous IEA Studies may not be valid for the South African situation;

- that South African Science curricula do not appear to be 'in step' with other international curricula; and
- that problem solving skills as well as other basic learning skills are not a readily available part of South African students' intellectual resources.

1.1.3 METHODOLOGY

1.1.3.1 Testing requirements of the TIMSS Study Centre

The vehicle to achieve the intended aims of this study, which are implicit in the fundamental premises listed above and made explicit below, is the Third International Mathematics and Science Study [TIMSS] of which the author of this thesis is the National Research Co-ordinator [NRC] based in the Human Sciences Research Council [HSRC]. The TIMSS study was aimed at three population strata in the school system. 'Population 1' is the term given to describe those students tested in the International Mathematics and Science Study from the South African Standards 2 and 3 [Grades 4 and 5, the fourth and fifth year of schooling]; 'Population 2' refers to those students in the South African Standards 5 and 6 [Grades 7 and 8]; while 'Population 3' refers to students in the South African Standard 10 [Grade 12] classes. A fuller definition of these study groups is given in Chapter Four.

1.1.3.2 Purpose of the investigative method of this study

Following the investigative method of TIMSS, this study is intended

- to investigate the opportunities that students are given to learn Mathematics and Science;
- to explore the methods by which these opportunities are realised; and

- to examine the outcomes of Mathematics and Science education in the South African and International context.

It should be noted that while the first two intentions are given some attention, the main focus of this thesis is, as already noted, on outcomes or achievement.

1.1.3.3 Procedure

The sequence of procedures followed involves:

- the collection, cleaning and selection of data
- the processing of data
- the interpretation of findings
- the drawing of conclusions and the making of recommendations.

1.1.3.3 (a) Selection of data

Data from over 11 000 Standard 5 and 6 student test papers and questionnaires were collected, captured and, after data cleaning, the remaining test papers and questionnaires of 9 987 students from the target group were analysed, using computer-based statistical programmes to achieve analyses that were identified as being informative in terms of the objectives of this study as set out above.

Although some sixty-three countries participated in various aspects of the three TIMSS 'Population' groups, this study is confined to 'Population 2'. Selected findings from four developed countries - France, Canada, Japan and Australia (one from each continent) - and all three other developing countries - Iran, Colombia and Thailand - are used for comparative purposes. South Africa is, of course, classified as a developing country. Reference to yet other countries is made as required for additional emphasis.

1.1.3.3 (b) The processing of data

Extensive use is made of the provisional TIMSS data base as a source for statistical material. This selected data is tabulated and merged with the South African data so that an analysis of national and international performance can be made. Overall performance, as well as performance in the eleven subject fields (six for Mathematics and five for Science) and performance in individual questions, is examined and compared.

1.1.3.3 (c) The interpretation of findings

In order to establish a theoretical basis to interpret the findings, the relevant literature has been read and evaluated. This provides a critical overview of learning strategies as they could be applied to South Africa. Relevant assessment techniques are deployed where necessary. The selected questions are examined for evidence of misconcepts as well as evidence, or lack thereof, of specific performance skills and environmental issues, and how these relate to teaching and learning theory and practice.

1.1.3.3 (d) Drawing conclusions and making recommendations

The overall survey of the TIMSS - South Africa is reviewed and attempts are made to offer recommendations to correct the identified shortcomings.

1.1.4 THE STRUCTURE OF THIS STUDY

After outlining the need for an objective empirical study of Mathematics and Science education in South Africa, this first chapter provides a statement of the problem to be investigated and articulates the aims and objectives of this thesis, within the investigative method of TIMSS and based on specific premises. A central component of the chapter deals in some detail with the methodology to be followed; and outlines the structure of this study. The acronyms and 'language' of TIMSS are introduced; and the background of the International Association for the Evaluation of Educational Achievement [IEA], which is the parent body under which TIMSS and other international studies of this kind operate is given. From the premise that the true wealth of a nation is determined by the intellectual wealth and skills of all its people, this chapter closes by providing justification for South Africa's participation in TIMSS, and by presenting a brief overview to highlight the educational thrust of this study.

Chapter Two forms the basis of this study and provides the theoretical background. It consists of an overview of theories of learning and language acquisition relevant to teaching and learning conditions in South African classrooms, with special reference to Mathematics and Science. Attention is also paid to issues of language, reading and comprehension, in the belief that language and reading difficulties are so substantial as to obscure a number of the basic problems of Mathematics and Science education. This chapter also includes, where appropriate, some reference to the correlation between the TIMSS test questions and the concepts necessary for the successful completion thereof. The chapter concludes with a summary of the important implications of learning theory for Mathematics and Science education.

In view of the fact that the social conditions under which this study was carried out are likely to become a matter of historical record in a very short time, it is deemed necessary to record the current socio-political status of South African education during the time of the TIMSS application in order to establish the contexts in which the testing and analysis were carried out. These contexts are set out in Chapter Three.

Chapter Four contains a core outline of the TIMSS study design and a discussion of local problems and shortcomings in regard to this design. The national sampling process is given in detail, finishing with an evaluation of both the TIMSS testing procedure and the process of curriculum analysis.

A preliminary analysis of the South African achievement record in the internationally comparative setting is presented in Chapter Five. These comparisons take on two aspects, namely, comparisons with four other nations that participated in TIMSS and more detailed comparisons with what are classed as Developing Nations, three of which (as already noted, in addition to South Africa) participated in TIMSS. A selection of TIMSS questions is illustrated and discussed. Where appropriate, an examination is made of student responses in terms of the theories of learning set out earlier in Chapter Two.

In the penultimate chapter, Chapter Six, the achievements described in Chapter Five are linked to the derived student profiles, and the interactions between student background and achievement are examined. Extensive attention is also given the impact of language on achievement.

The concluding chapter discusses notable features of South Africa's performance within the TIMSS context and offers some suggestions and recommendations about curricula, teaching and learning for the restructuring of Mathematics and Science education in a developing country. Finally, the principal deductions from previous IEA studies are tested against the South African findings.

1.2 WORKING DEFINITIONS AND TERMINOLOGY

Robert Gagné (1977: 114) notes that 'definitions are statements that express rules for classifying'. While this is the basic form, a number of definitions are more complex and can, for example, be subdivided into distinctions between 'features' and 'functions' (Klausmeier, 1971: 4). However, neither representation suffices fully to describe the usage of the term 'definition' in this study.

As with many large organizations there arises a system of internal language which tends to be cryptic and efficient for the participants. Set out below is a brief explanation or working definition of the nomenclature used and its specific meaning in the context of the TIMSS study.

- **Achievement** refers to student scores based on performance in the TIMSS testing instruments.
- **Core Cluster and Anchor Items** In each of the TIMSS test books there is a cluster or group of questions that is common to all the books. This cluster, Cluster A, is intended to provide a compact 'anchor' component of questions that were obligatory for every participating student.
- **FRI** (Free Response Items) These are question items that require the student to construct his/her own written response to the question posed.
- **IEA** The International Association for the Evaluation of Educational Achievement, which is the umbrella body under which TIMSS operated.
- **INSET** (In-Service Teacher Training) Professional Training and Development that takes place during a teacher's working life after certification.

- **LES** (Language in Education Study) A proposed study by the IEA on the mastery of language of instruction in schools.
- **Mother Tongue, First Language and Second Language** First language and mother tongue means 'the language a child acquires from his/her parents, family and immediate environment from the moment of birth' (Basel, 1995: 7). Second language is any language that is learned subsequent to the acquisition of the mother tongue. In this study, this is the case where the language of instruction is neither the mother tongue nor the first language. South Africa has no less than eleven officially recognized languages and a number of other minority languages. Within the parameters of TIMSS, testing was carried out in the language of instruction (that is, the language that is used in the school classroom) which in more than 82% of cases was not the language the students use in communicating with their peers or parents.
- **NGO** (Non-Government Organization) There are over one hundred registered organizations (Levy, 1993) outside the formal Education Departments that contribute to Mathematics and Science education in South Africa. Many of these organizations exist in an attempt to address the shortcomings of the education system of the past. These NGOs are funded variously from foreign aid, domestic corporations and companies in addition to fund-raising in the private sector. In addition, a large number of companies such as DENEL, SASOL, ISCOR, NAMPAC, Richards Bay Minerals and many others mentor schools and provide enrichment programmes in Mathematics and Science.
- **NRC** (National Research Co-ordinator) This is the designated person responsible for the control and leadership of TIMSS programmes in each of the participating countries.
- **Pop 1** (Population 1) This is a sample group of students taken from Standards 2 and 3 [Grades 4 and 5] for the purposes of TIMSS testing. South Africa did not participate in Pop 1 testing. (The reasons for this are set out in Chapter Four.)

- Pop 2 (Population 2) This is the sample group of students taken from Standards 5 and 6 [Grades 7 and 8]. This group is the focus of this study.
- Pop 3 (Population 3) This group is a sample drawn from those students in their final year of schooling. For the purposes of the South African investigation this was taken to be those students in Standard 10 [Grade 12]. Little attention is paid to this group in this study.
- Rotated Question Clusters To allow testing on as wide a spectrum of material content as possible the TIMSS solution is to distribute clusters or groups of questions in a predetermined sequence throughout the eight test books. Thus all the students in the sample are not asked to answer all the questions.
- SIMSS The Second International Mathematics and Science Study (1983-1986).
- TIMSS The Third International Mathematics and Science Study (1995). It is intended that a second international round of TIMSS will take place in 1999. The HSRC also plans to develop TIMSS type studies into a South African longitudinal study.

Before proceeding with a discussion of the reasons for South Africa's participation in TIMSS, a fuller explication of the IEA is needed to provide the international context for this educational survey [TIMSS].

1.3. THE INTERNATIONAL ASSOCIATION FOR THE EVALUATION OF EDUCATIONAL ACHIEVEMENT [IEA].

1.3.1 HISTORICAL BACKGROUND

The International Association for the Evaluation of Educational Achievement [IEA] was founded in 1959 (Keeves, 1995). The broad aim of this association is to make comparative studies on an international basis and to identify successful systems and methods where possible. The

Association presently consists of a grouping of over seventy national Ministries of Education and national research institutes (Keeves, 1995: 61). Since its founding, thirteen international studies have been completed by the IEA (See Table 1.2 below) and the Third International Mathematics and Science Study [TIMSS] has recently been completed. The formal report-back to participating nations was at the end of November 1996, for Population 2; and one other study is being contemplated and is in the early stages of planning, that is, the Language in Education Study [LES].

1.3.2 THE IEA MISSION

The aims of the IEA (IEA, 1994: 1) are encapsulated in its mission statement:

> The International Association for the Evaluation of Educational Achievement [IEA] is an independent international co-operative of research centres. It has taken as its mission the conduct of comparative studies focusing on educational policies and practices in order to enhance learning within and across systems of education. The IEA has committed itself to a cycle of studies of learning in the basic school subjects and to additional studies of particular interest to its members.

The specific features which distinguish IEA studies (IEA, 1994: 1) include the following:

- By being international and co-operative [these studies] enable researchers and policy makers to enter into a dialogue with, and learn from their colleagues around the world and they enable systems of education to view more clearly their unique cultural situation from an international comparative perspective.

In focusing on educational policies and practices, [these studies] start with developing a conceptual framework that clarifies the issues, suggests appropriate methods of investigation, results in validated measures of educational outcomes and processes, and uses those analytic tools that can best elucidate key factors and issues.

1.3.3 IEA STUDIES

The management practice for IEA studies has been refined over the years and the present policy is that a Study Centre is contracted to manage the study under the auspices of the IEA International Executive and Congress. In the case of TIMSS, the Study Centre is at Boston College, Massachusetts, USA. The Study Director is Professor Albert Beaton, who heads a large dedicated team of researchers. The international management component of TIMSS is distributed among various centres of excellence throughout the world, as indicated in Table 1.1 below.

At the national level, each participating nation is required to identify a National Research Co-ordinator [NRC] based in an acceptable research institution to manage the project. The institution is obliged to demonstrate that there are the national or institutional resources and experience to carry the study to completion.

Table 1.1 TIMSS Management Centres

FUNCTION	RESPONSIBLE ORGANIZATION
TIMSS Study Centre	Boston College - Boston, Massachusetts, USA
International Co-ordination	University of British Columbia, Vancouver, Canada.
Data Processing Centre	University of Hamburg, Hamburg, Germany.
Test instruments	University of York, Ontario, Canada.
Curriculum Analysis	Michigan State University, East Lansing, Michigan, USA.
Statistical Systems	Australian Council for Education Research, Melbourne, Australia.
Statistical Processing	Statistics Canada, Montreal, Canada.

NOTE: Within the TIMSS structure there is a large number of single purpose oriented specialist committees dealing with various aspects of TIMSS.

The South African TIMSS 'team' consists of an NRC, as already noted, plus two researchers and a clerk. When necessary, and at critical stages in the programme, senior staff are seconded for short periods from the Departments of Education or experienced teachers and other less skilled workers are retained on a 'piece work' basis to meet specific deadlines and requirements. At the various stages of TIMSS over two hundred and fifty people received training in such areas as curriculum analysis, free response item coding, data capture and cleaning as well as large clerical operations such as collating twelve thousand student packs.

1.3.4 CURRENT AND COMPLETED IEA STUDIES

As the Table 1.2 below shows, fourteen studies have so far been completed over a period of thirty-six years. Of these only two were in Mathematics and two in Science. All the other IEA international studies have been 'one of' studies in particular subjects.

Of the studies currently in progress, the only subjects that are planned to receive further attention are Mathematics and Science. This lends credence and value to the importance of these subjects in the estimation of international educators. In South Africa, negotiations are presently in progress for a second application of the TIMSS Study in 1999/2000 to add a longitudinal aspect to this cross-sectional programme.

Historically, negotiations by the author to participate in TIMSS proceeded for more than two-and-a-half years before South Africa was able to affiliate to the IEA. The HSRC indicated an interest in joining the TIMSS study in late 1993. Dr S.W.H. Engelbrecht is the Human Sciences

Research Council representative on the IEA General Assembly. As already alluded to, the writer of this thesis became the TIMSS National Research Co-ordinator, late in 1993.

Table 1.2. Completed and current IEA studies

COMPLETED STUDIES	YEARS OF TESTING
First Pilot Study	1960
Mathematics I	1964
The Six Subject Study	1970/71
Science	1970/71
Reading Comprehension	1970/71
Literature	1970/71
English (Foreign Lang.)	1971
French (Foreign Lang.)	1971
Civic Education	1971
Mathematics II	1980/82
The Classroom Environment	1982/83
Science II	1983/86
Writing	1985
CURRENT STUDIES	
Pre-primary (as yet incomplete)	1987 & 1992
Computers in Education	1989/1992
Mathematics and Science III (TIMSS)	1995 & 1996
STUDY IN THE PLANNING STAGES	PROPOSED YEAR OF TESTING
Language in Education	1997

1.4 THE REASONS FOR SOUTH AFRICA'S PARTICIPATION IN THIS INTERNATIONAL COMPARATIVE STUDY

1.4.1 ADMINISTRATIVE INCENTIVES FOR PARTICIPATION IN IEA STUDIES SUCH AS TIMSS

The re-admission of South Africa into an international context after many years of isolation suggests that it is also time to examine the broad scope of South African educational achievement and this thesis seeks to make a contribution by presenting and evaluating the results of the Third International Mathematics and Science Study in South Africa. This focus is even more relevant and significant in the light of the broad spectrum administrative and political emphasis on Mathematics, Science and Technology in Primary, Secondary and Tertiary education in a democratic South Africa (Technology Forum, 1994; Department of Arts, Culture, Science and Technology, 1994; Project 2000, 1995; Department of Education, 1995 (a)) .

1.4.1.1 Recent historical incentives

As long ago as 1965 the late Dr S. Meiring Naudé, in his presidential address to the Association of Scientific and Technical Societies (Meiring Naudé: 1965), issued a clear warning to South Africa about the failure of the education system to train the scientists and technicians that the nation requires. Although a considerable amount of research has been completed in the intervening years, the Human Sciences Research Council's investigation into education (known as the de Lange Commission) (1981) underlines the same problems of low enrolments in Mathematics and Science courses (Human Sciences Research Council, 1981, Vol.1: 151); unsuitable curricula (*op. cit.*: 42); and unsuitable teaching methods (*ibid.*). Le Roux (1981) underlines the weak situation of South African Mathematics and Science Education further. These problems are discussed more fully in Chapter Three. Perhaps the most prophetic of these 'early' warnings was made by an unnamed delegate at the 1982 Association of Scientific and Technical Societies [AS&TS] Annual Conference at the Council for Scientific and Industrial Research [CSIR] Conference Centre when he maintained that South Africa would miss any economic upswing because the nation could not staff it with engineers and technologists. These warnings were reinforced by the findings of the enquiry initiated by the Chairman of the Scientific Advisory Council (then Dr W. de Villiers) in 1984. A number of succeeding research documents including '*The Hidden Crisis*' (Pouris, 1989), Lombard's report (1991), and *Building the Base* (Kahn, 1993) have all been powerfully motivated enquiries but have failed to achieve the necessary impact in the classroom. Pouris (*Pretoria News*, 1989: 4) draws attention to the diminishing numbers of students who enter post-Standard 7 studies in Mathematics and Physical Science, and the falling numbers of successful Matriculants in these subjects. In economic terms, he also considers the falling numbers of Tertiary Education graduates in Mathematics, Science and Engineering to be no less than a 'crisis'.

1.4.1.2 Contemporary incentives

More recently the 'Education Renewal Strategy' (Department of Education, 1992: 70 and 89), the ANC 'A Policy framework for Education and Training' (1994 (a): 97-101) and the ANC 'Implementation plan for Education and Training' (1994 (b): 44) all draw attention to the problems that beset education. Ironically though, the national Science and Technology policy green paper (Department of Arts, Culture, Science and Technology, 1994) makes no reference to scientific and technological manpower or the training thereof in South African schools. Arguably none of these analyses has had the impact on the nation that the '... Nation at Risk' (National Science Foundation, 1985) report had on Mathematics and Science education in the United States of America. According to an article entitled 'Technology: A National Imperative' (Technological Education Advisory Council of America, 1989: 25), the Technological Education Advisory Council of America injected an amount of $US 250 000 000 into education in these subjects in the eight years following the publication of the former document. As stated in the 'Message from the Minister of Education, Professor S.M.E. Bengu' (Department of Education, 1995 (a): 1) in the final version of the white paper on 'Education and Training in a Democratic South Africa':

> Education and training are central activities of our society. They are of vital interest to every family and to the health and prosperity of our national economy. The government's policy for education and training is therefore a matter of national importance second to none.

In the same document, in a discussion on Policy development and strategic plans in transition' (*ibid.*: 2), however, a cautionary note is sounded: 'Policy is important, but execution is more important'. From the TIMSS findings, it would appear that South Africa has lacked sorely in 'execution' for many years now.

1.4.1.3 The specific characteristics of TIMSS as an incentive

As mentioned earlier in this section, South Africa has, for a number of years, been aware of the shortage of qualified manpower in scientific fields. None of the three other national initiatives, already undertaken to meet this need and as specified in the opening paragraphs of this chapter, has focused specifically on achievement in Mathematics and Science education; nor do they present a national picture compared to a global one as the TIMSS study has done. Despite the fact that some participating countries in TIMSS were permitted to subdivide their populations - for example, Belgium treated their French speaking and Flemish speaking populations as entirely separate groups, and Israel did not apply the tests in Arabic schools - no consideration was given to a South African sample other than one which was representative in absolute terms. The sampling process used in South Africa is described more fully in Chapter Four. As far as can be ascertained, this is the first national education survey to treat the South African population as a coherent unit for sampling and testing purposes. Earlier studies have tended to be racially divided (cf. von Mollendorf, 1978; Verwey, 1980; Chamberlain, 1980; van Niekerk, 1984; Hugo & Claasen, 1991); analytical in terms of education department curricula (Visser, 1991); and investigative in terms of enrolments and achievement within the School Leaving Certificate examination written by the students (Mitchell & Fridjhon, 1987: 555-558).

A considerable amount of recent work has also been carried out at several universities (cf. Kendall, 1990; Ntho, 1992; Rossouw, 1992; Moodley, 1993; Laridon & Glencross, 1995; Basson, Goosen & Swanepoel, 1996) concerning learning processes, concepts and misconcepts and smaller-scale pre- and post-test investigations. Through a more holistic approach to the capture and interpretation of data, TIMSS has, on the other hand and as already intimated, been able to provide a national and international picture of achievement. In South Africa's case, these findings can be linked to economic theory to propose an indication of future development capacities.

1.4.1.4 Broad educational incentives

There is a growing awareness that a nation's well-being depends, to a large extent, on the education level of its population and on the nation's ability to prepare and produce from its own education system the human resources needs to maintain and expand its productivity base. The wealth of a nation, as already suggested, arises from the intellectual wealth and skills of its people (Epicurus in Catrevas *et al.,* 1965: 721):

> The Wealth of a State consists not in great treasures, solid walls, fair palaces, weapons and armour; but its best and noblest wealth, and its truest safety, is in having learned, wise, honourable and well-educated citizens.

A proposition of this thesis is that education and quality of life are inextricably interrelated.

IEA projects such as TIMSS are carried out for two important reasons, both of which are highly relevant to South Africa in its current state of social and political reconstruction and change.

- To assess the potential impact that alternative curricula, teaching and administrative strategies have on student achievement within countries; and,
- to provide current international information which countries can use to compare and contrast their curricula, teaching practices and student outcomes with those from other countries of interest.

1.4.2 FURTHER REASONS FOR PARTICIPATING IN TIMSS

In addition to the rationale set out above for entering into a long term and inevitable costly international evaluation of achievement exercise, there are numerous and compelling benefits to participation. Further reasons for participation can be grouped under three general headings:

- Academic reasons,
- Education Management and Planning reasons, and
- Economic reasons

1.4.2.1 Academic reasons

An extract from the original stated aims listed in the 'The IEA: People and Activities' (1993: 3) articulates the academic importance of this international study as:

TIMSS AIMS

- To provide current national and international information that education systems can use to evaluate their curricula, teaching practices and student achievement outcomes and to compare these with other systems of interest.

- To assess the potential impact that alternative curricula offerings, teaching strategies and administrative arrangements could have on learning.

- To identify what is possible in the teaching of Mathematics and Science by identifying factors that might extraordinarily influence growth rate of knowledge and skills in these areas.

- To obtain greater understanding of how and why student attitudes change, and in particular what relationship there is between classroom practices and positive attitudes towards Mathematics and Science.

In the context of South Africa's past isolation it seemed that there would be considerable gains from participating in TIMSS. The Constitution made this 'added value' even more pressing and with this in mind additional objectives were formulated and submitted with the original research proposal to the HSRC executive.

Appended South African objectives which appear in the original HSRC proposal (Gray, 1993: 5) and which will be dealt with later in this study include:

- The [researcher's] perception of this programme is that there will NOT be many direct gains, except for determining long term policy and planning goals, by making comparisons between South African achievements and the achievement levels in first world countries such as Sweden or the USA or

Canada. However there is much to be gained by making comparisons between South Africa and developing countries such as Mexico, Brazil, Malaysia and some of the emerging Eastern European countries.
(Note: Colombia, Thailand and Iran were the only participating developing countries that were reported on by TIMSS.)

- Significant benefits are to be gained by making comparisons between South African achievements in this programme and the achievement levels in our economic equals and direct economic competitors.

- In terms of the Constitution, Education, at school level, has been devolved to a provincially managed function. However, the Central Government has retained control over Norms and Standards. This implies measurement, particularly in the critical subject areas of Mathematics and Science. TIMSS and associated programmes would appear to fit these control requirements admirably.

In the longer term, TIMSS is intended to become the main component of a more wide ranging longitudinal survey of achievement in Mathematics and Science using both TIMSS and HSRC generated test materials. It is hoped, that by basing a survey, such as this, on school institutions rather than on individuals we will be able to generate a longitudinal image of scholastic performance, trends and effects of changes on achievements on a national basis. This will be of considerable value to Education Administrators, Planners and other interest groups.

It should be noted that TIMSS does not seek to develop or identify a Universal Curriculum; nor does TIMSS wish to develop a universal methodology for Mathematics and Science education.

1.4.2.2 Education management and planning reasons

1.4.2.2 (a) Previous Comparisons of Education Achievement

Historically, under the apartheid system, South African education was racially divided. With the new social and political dispensation, inter-provincial comparisons of achievement will provide essential data for compiling coherent national education planning programmes and for identifying issues and needs for the budgetary process.

1.4.2.3 Economic reasons: the Wealth of Nations

1.4.2.3 (a) The source of a nation's wealth

Recent changes of policy in the World Bank on the reporting of the wealth of nations has introduced major and significant changes to their methods. Whilst the traditional indicators - such as Gross National Product, National *per capita* Income and productivity indices - have not been discarded, this new system, which is still being developed, appears to be far more equitable and fair to all nations and would appear to avert some of the criticisms of the more established indices.

The new reporting system classifies the wealth of a nation as divisible into three aspects as indicated in Table 1.3 below. It is the third category, Human Resource investment, which acknowledges education as one of the indices for 'measuring the wealth of a nation'. This is, at once, the most exciting addition and the most important in terms of this survey as can be seen from the following extracts from a World Bank Draft Report, *Sustainability and the Wealth of Nations* (Serageldin, Annex 1, 1995: 1-4).

Table 1.3 The Wealth of Nations

THE WEALTH OF NATIONS

- The wealth of natural resources, i.e. the national mineral wealth and other diminishing resources and renewable resources such as tourism attractions, agriculture and forestry production etc..

- The created or produced wealth of a nation, i.e. that wealth created by its industrial production, investment in roads and bridges and other infrastructure that facilitates production.

- A Nation's Human Resource Investment. This is wealth which includes health and nutrition and educational levels.

1.4.2.3 (b) Data extracted from an analysis of the Wealth of Nations

Table 1.4 The five wealthiest nations of the world

Rank Order	COUNTRY	Estimated Wealth *	Human Resources	Produced Assets	Natural Capital
192	Australia	$ 835 000	21%	7%	71%
191	Canada	$ 704 000	22%	9%	69%
190	Luxembourg	$ 658 000	83%	12%	5%
189	Switzerland	$ 647 000	78%	19%	3%
188	Japan	$ 565 000	81%	17%	2%

Note: [*] = Estimated Wealth *per capita*

Table 1.5 The 'poorest' five

Rank Order	COUNTRY	Estimated Wealth *	Human Resources	Produced Assets	Natural Capital
1	Ethiopia	$ 1 400	40%	21%	39%
2	Nepal	$ 1 600	56%	27%	17%
3	Burundi	$ 2 100	67%	26%	7%
4	Malawi	$ 2 200	42%	32%	26%
5	Uganda	$ 2 300	18%	51%	32%

Table 1.6 South Africa and its nearest economic neighbours in the Wealth of Nations scale

Rank Order	COUNTRY	Estimated Wealth *	Human Resources	Produced Assets	Natural Capital
121	Estonia	$ 55 000	71%	14%	14%
122	Malaysia	$ 56 000	59%	16%	23%
123	Venezuela	$ 58 000	39%	23%	36%
124	**South Africa**	**$ 61 000**	**40%**	**14%**	**46%**
125	Uruguay	$ 61 000	56%	14%	30%
126	Hungary	$ 63 000	72%	16%	12%
127	St Kitts/Nevis	$ 68 000	77%	18%	5%

1.4.2.3 (c) Education and South Africa's involvement in international achievement studies

The deductions that can be made from the figures above and the rhetorical question posed by Kahn (1994: 3) in the *Siemen's Spring Review*,

> "Is competition in world markets essentially a competition between education systems?"

give strong support for South Africa's involvement in International Achievement Studies.

1.4.2.3 (d) An interpretation of the tables

Achievement levels in international studies can serve as a useful predictor for a nation's future economic performance.

South Africa's performance, when compared to the performance of developed northern hemisphere countries, should not be over-emphasized but it will provide a significant indicator in terms of setting long term goals and objectives. As stated earlier, what is of importance is South Africa's performance compared to economic equals and economic competitors, such as Thailand, Malaysia, Mexico, Colombia and the emerging Central European countries. Such collateral information, derived from TIMSS, will be of value to South Africa's education and economic planners and forecasters.

South Africa's economically competitive future does not look very promising in terms of its national investment in school leaving qualifications which bear little relationship to development and yield a poor return. Less than 15% of school leavers attempt to write the examinations in Physical Science and less than half of these pass (see details in Chapter Three). An even smaller proportion have passes of sufficient quality to make their admission to tertiary education a justifiable risk. This issue is returned to in Chapter Seven.

The United States of America, which does not feature in the top ten in the 'wealth of nations' scale and therefore does not feature in the examples shown above, found its national performance in the Second Mathematics and Science Study [SIMSS] to be poor and the result has been that for the past eight years there has been a dramatic restructuring of education to create job creators through the sciences, engineering and technology. The public release of TIMSS findings, published in November 1996 as already noted, reveals that this national effort has not been effective in terms of improved performance - certainly in the past three to four years the United States economy has strengthened as has that of other nations with a high national wealth in their human resources.

1.4.2.3 (e) Spearman's rank order correlation between Human Resource investment and achievement in TIMSS.

An application of Spearman's Rank Order (Ferguson, 1959: 216-220) correlation co-efficient to examine the relationship between National Achievement and rank order of Human Resource investment reveals a positive correlation of 0.38 which is a correlation significant enough to support a hypothesis that National achievement correlates significantly with Human Resource investment. This relationship is examined more fully in Chapter 3. This degree of correlation serves to underline one of the reasons for the TIMSS study being important to South Africa.

Table 1.7 Spearman's rank order correlation calculation

$$\rho = 1 - \frac{6 \Sigma D^2}{N(N^2 - 1)}$$

$$= 1 - \frac{6 \times 9\,651.0}{41(41^2 - 1)}$$

$$1 - \frac{41\,706}{66\,921}$$

$$= 1 - 0.62 = 0.38$$

Key:
ρ = correlation coefficient
Σ = sigma = the sum of
D = rank order differences
N = number countries in the samples being correlated

	ACHIEVEMENT RANK X	HRD WEALTH	HRD RANK Y	RANK DIFFERENCE X-Y	$(X-Y)^2$
1. Singapore	1	85	4	-3	9
2. Korea	2	88	1=	0.5	0.25
3. Japan	3	81	9=	-7	49
4. Hong Kong	4	88	1=	2.5	6.25
5. Belgium Fl.	5	83	5=	-1	1
6. Czech Rep.	6	66	28=	22.5	506.25
7. Slovak Rep.	7	78	16=	10	100
8. Slovenia	8	67	27	19	361
9. Switzerland	9	78	16=	8	64
10. Netherlands	10	80	13	-3	9
11. Bulgaria	11	61	32	21	441
12. Austria	12	75	22=	-10.5	110.25
13. France	13	77	19	- 6	36
14. Hungary	14	72	24	-10	100
15. Russia	15	15	41	-26	676
16. Australia	16	21	40	24	576

17. Ireland	17	76	20=	-3.5	12.25
18. Canada	18	69	26	-8	64
19. Belgium Fr	19	83	5=	12.5	156.25
20. Thailand	20	81	9=	10	100
21. Israel	21	86	3	17	289
22. Sweden	22	56	35	-13	169
23. Germany	23	79	14	9	81
24. New Zealand	24	40	37	-13	169
25. England	25	83	5=	18.5	342.25
26. Norway	26	48	36	-10	100
27. Denmark	27	76	20=	-6.5	42.25
28. United States	28	59	33=	-5.5	30.25
29. Scotland	29	83	5=	22.5	506.25
30. Latvia	30	66	28=	1.5	2.25
31. Spain	31	78	16=	14	196
32. Iceland	32	23	40	- 8	64
33. Greece	33	75	22=	10.5	110.25
34. Lithuania	34	62	30=	3.5	12.25
35. Romania	35	70	25	10	100
36. Cyprus	36	79	13=	22.5	506.25
37. Portugal	37	81	9=	27	729
38. Iran	38	34	39	-1	1
39. Kuwait	39	62	30=	8.5	72.25
40. Colombia	40	59	33=	6.5	42.25
41. South Africa	41	35	38	3	9
					Σ = 6 951.00

1.5 SOME CONSTRAINTS UNDER WHICH TIMSS - SOUTH AFRICA OPERATED

This study presents the initial findings of a major study conducted under the auspices of the IEA in South Africa from the vantage point of the National Research Co-ordinator for the TIMSS. In South Africa, the profile of these findings is more complex than most, as the achievement levels attained reflect factors other than those of scientific knowledge. A key issue, unique to South Africa, which almost certainly prejudiced performance, is that most participants were responding in a second or third language and not in their mother tongue. This crucial issue and its impact on performance is discussed more fully in Chapters Two and Six.

Furthermore, at the time when the TIMSS test administration personnel were ‘in the classroom’, much of the school system was characterized by ‘chalk-downs’ and student unrest which severely disrupted the education process for much of the school year. It is also pertinent to note that 1994 was the year of the first democratic elections, when new conditions for living were being vociferously and vigorously explored by the youth of South Africa. This unrest spilled over into 1995 to a very substantial extent.

1.6 OVERVIEW

In closing, it is important to note that although the economic reasons for South Africa's participation in TIMSS, discussed above, are crucial, they are somewhat tangential to the main purpose of this study. This opening chapter has argued that the TIMSS tests are designed to measure Mathematics and Science achievement, in order to provide crucial information for governments, policy makers and educators about the proficiency of their students at key points in the educational process, while the questionnaires are designed to collect information about factors related to students' learning of these subjects (Human Sciences Research Council, 1996: 2):

TIMSS was designed to assess national curricula, school and social environment and achievement in Mathematics and Science in all participating nations across the world.

CHAPTER 2

AN OVERVIEW OF RELEVANT LEARNING THEORIES AND THEIR IMPLICATIONS FOR MATHEMATICS AND SCIENCE IN SOUTH AFRICAN SCHOOLS

2.1. EARLY LEARNING THEORIES

2.1.1 THE SOCIO-HISTORICAL MILIEU OF LEARNING THEORY

Scientifically based theories of learning show a diachronic development that closely relates to the synchronic scientific and social values of the period and the country in which they arose. And whilst neither the values nor the climate in which these theories were evolved can be directly transposed to the South African situation, the generalized theories of learning inevitably affect both academic and classroom teaching practice, directly and indirectly. Moreover, as no theory in education can develop in a social vacuum, the exponents of the various theories are best viewed more or less chronologically. One of the outcomes of such theoretical studies is that learning and teaching theories must, inevitably, provide guidelines for the teacher in order to optimise the learning process and thus signpost the routes to future developments in education in this country.

Theories of learning relevant to Mathematics and Science Education can be divided into two broad schools of thought: those focusing on Mathematics as simple number processing and Science as the mere acquisition of 'facts' (as propounded by the Behavioural psychologists) on the one hand; and those focusing on problem solving and concept formation in both Mathematics and Science (as propounded by the Cognitive psychologists) on the other hand.

One of the basic problems of learning that became all too apparent from responses to the TIMSS questionnaires in South Africa is directly related to these two approaches to learning. For example, responding to advertizing 'fact' rather than scientific fact, in a content based Science question, more than half the students opted for vitamins rather than the sun as the chief source of energy in food (see Appendix 1 - detailed performance data for this question appear in Chapter 5). Also, in a concept based Mathematics question, only 5.5 per cent of South African students were able to give any sort of correct answer to a question that required them to write a fraction larger than 2/7. (Detailed performance data for this question appear in Chapter 5.) For the lower primary school student, this latter question would pose a serious degree of difficulty, calling as it does upon several quite complex concepts in number theory; whereas for a student in the seventh or eighth year of school, who has already mastered concepts such as number value, the meaning of fractions and the 'value' of the denominator and the 'value' of the numerator, the answer should have been readily available.

Such basic lack of information and lack of understanding of concepts point to the fact that learning and teaching are a much more complex process than is generally appreciated, particularly in scientific subjects. As Orton (1992: 8) confirms:

> It was Skemp (1964) ... who stated the view that fractions provide the obvious example of a mathematical idea previously considered to be elementary which analysis of concept reveals to be far from simple.

It follows that the teacher, who through exposure to not one but many learning theories understands such complexities, will inevitably be more effective than one who has not had the benefit of such knowledge. One of the reasons why In-Service training, although not a focus of the present study, is so valuable in the 'new' South Africa is that large numbers of teachers appear to lack proper training in the Theory of Education. For convenience and following Entwistle (1987: 5), the relevant trends and developments in Learning Theories can be tabulated as follows:

Table 2.1 Learning theories, concepts and applications relevant to TIMSS - South Africa

TYPE OF THEORY	EXPONENTS OF THE THEORY	ASSOCIATED TECHNIQUES AND CONCEPTS
Behaviourist	Thorndike	Stimulus response, rapid reward
	Pavlov	Conditioned learning
	Watson	
	Skinner	Programmed learning and CAI
	Bloom	Mastery Learning
Insightful	Hull	Formation of memory maps
	Köhler	Problem solving by insight
	Harlow	
Cognitive	Ausubel	Advance organizers and cognitive maps
	Resnik	Task analysis
	Piaget	Cognitive development and intellectual maturation.
	Gagné	Phased learning

Because the focus of this study is on TIMSS and not on learning theories *per se,* these three groups of theorists are discussed briefly below in that the theories discussed appear to have the greatest relevance to the South African education process.

2.1.2 BEHAVIOURIST LEARNING THEORIES

Learning theories begin with those broadly classified as Behaviourist. Behaviourist learning theories may be regarded as evolutionary derivatives of Thorndike's approach (1932: 122) to learning based on the logic of connectors:

> I find connections of varying strength between (a) situations, elements of situations and compounds of situations and (b) responses, readiness to respond, facilitations, inhibitions and directions of responses. If all these could be completely inventoried, telling what man would think and do and what would satisfy and what would annoy him, in every conceivable situation, it seems to me that nothing would be left out ... . Learning is connecting [my emphasis]. The mind is man's connection system.

While the simple equation 'Learning is connecting' would tend to align Thorndike (and other behaviourists) with the 'science as fact' approach to learning, ignoring the essential meaning of the experience, the final sentence of the quotation could be regarded as a pointer to the theory of Cognitive Mapping discussed later in this chapter, which addresses the ever growing problem of information processing by providing a procedural methodology for both the student and the teacher. In this way, Thorndike's maxim 'learning is connecting', coupled with his logic of connectors, highlights the important interrelationship of scientific theories of learning.

2.1.3 THE FOUNDERS OF BEHAVIOURIST LEARNING THEORIES

2.1.3.1 E. L. Thorndike

Although Thorndike is generally regarded as the pioneer of 'associative learning', Kant had, in fact, prefigured Thorndike's theory when he claimed that: 'man can only acquire knowledge by means of his conscious experience ...' (Thomson, 1968: 43). Largely owing to Kant's further insistence that it is wrong to infer from experimental data that there is something beyond individual experience, the impact of Kantian phenomenology tended to influence philosophy and psychology, rather than education. Thus, from an historical point of view, it is Thorndike who is regarded as a leading precursor of 'scientific' learning theory.

Thorndike developed a 'trial and error' learning theory based on systematic scientific observations. For example, one of his classic experiments involved observations of a cat in a 'puzzle box'. By careful observation, he developed learning curves based on measured time for the subject animal to 'solve a problem' such as escaping from the box.

This approach to learning came to be called the 'School of Functionalism' which permitted 'the functions of the mind to "share the spotlight" with practical applications' (Miller, 1962: 227). Although Thorndike asserted that learning is a 'blind' process of 'trial and error' (Gagné, 1977: 8), he surmised that it is, to some extent, also governed by three principles (Borger & Seaborne, 1966: 25). The first is the principle of 'contiguity' in which the stimulus and response must occur in close succession to each other. It is a variant of this law that Hull later uses as the foundation of his Stimulus-Response (S-R) theory of learning (Miller, 1962: 227).

The second, the principle of 'exercise', states that the stimulus-response process must be repeated often. This principle is based on the observed fact that 'an act that has a satisfying reward will be learned, (and repeated), whereas acts that have an unpleasant effect will not be learned (Thorndike, 1913: 4). In other words, acts resulting in negative effects will be avoided (Morgan, 1961: 190). The third principle of learning is that of 'effect'. This principle suggests that only actions that are rewarding are likely to be repeated. As Miller (1962: 221) notes, 'feedback helps to strengthen the association between the stimulus and the correct response'. The relevance of these principles to the classroom situation remains valid. For instance, delays between a student writing a test (the action) and receiving the results (satisfaction) does not contribute positively to learning. Thorndike thus regards learning primarily as the 'association' between a stimulus and the reward of a correct response. The generalized results of the Third International Mathematics and Science Study, which are intended to measure national performance, and which was treated as a low stakes test in the classroom, could conceivably be regarded as pedagogically unsound as there is no intention of, or possibility of direct feedback of results to students. However, it should be stressed that feedback to participants was not one of the aims of TIMSS.

Biggs & Telfer (1987: 146-147) express ideological reservations about Thorndike's theory in that, 'He believed that there was a continuity between animal and human learning'. Other more objective criticism of learning within Thorndike's experimental situations is that no learning has actually taken place as no new skills have been developed. Brownell (Orton, 1992: 179) underlines this rebuttal of Thorndike by asserting that learning must be based on understanding the process band of underlying principles rather than on isolated facts and/or observations. In early learning situations, Thorndike's approach to learning is still relevant although, as Brownell (Resnick & Ford, 1981: 17) observes:

> ... drill simply made them [the students] faster and better at the "immature" procedures they had discovered for themselves, not at the kind of direct recall that adults possess.

It follows that, at a more conceptual level, Thorndike's approach offers no practical explanation for the formation of advanced constructs or for the formation of formal concepts that cannot easily be concretized.

2.1.3.2 H. Ebbinghaus

Ebbinghaus approaches the question of learning by limiting 'associative' learning to an examination of learning by 'verbal' associations. He investigated recall from a memorized list of nonsense syllables and the decay of this memory with the passage of time. Subsequent investigations by Kingsley & Garry (Morgan, 1961: 237) examine the difference between knowledge decay of nonsense, as opposed to that of meaningful material. In the latter case, the retention curve is less steep but still follows what may be termed as the general 'Ebbinghaus' trend of an initial rapid loss of memory which becomes less steep with the passage of time. The main weaknesses of these studies lie in the emphasis on rote learning rather than on concept building or problem solving.

However, such theories have had an impact as aids to learning basic facts and algorithms. For example, teachers still use mnemonics as effective teaching and learning aids. BOMDAS (Brackets of Multiplication, Division, Addition and Subtraction) is useful in early Mathematics for students to remember the order in which basic arithmetical processes are to be applied. BOMDAS may possibly have been helpful with some of the fractions questions in the TIMSS test papers. POLECAT (Positive ions LEave at the CAThode), too, is often used in secondary school Chemistry. This technique is relevant to students, who can be encouraged to construct their own word associations as an aid to learning and memory.

2.1.3.3 I. Pavlov

In what may be seen as an extension of Thorndike's 'associative' learning theories, and which takes a conceptual leap forward, are the Pavlovian 'Classical Conditioning' and 'Respondent Conditioning' theories. Pavlov's contribution to learning theory lies in his identification and investigations into the Conditioned Response, its mechanism and its control. According to Biggs & Telfer (1987: 146-147), Pavlov's work and that of his successors is still the basis for mind control and advertizing in the modern world (Hammerton, 1954:: 6377). Like Ebbinghaus, Pavlov studied the extinction times for conditioned behaviours. Investigations into higher order conditioning (the use of one conditioned response to build up another conditioned response) led Pavlov into more complex aspects of conditioning in which the stimulus eliciting the response is changed by linking a conditioning stimulus to another stimulus. For example, a dog is conditioned to a bell to expect food. If a card is repeatedly placed in the dog's vision just before the bell sounds, the dog soon begins to salivate on sight of the card. In other words, the dog is now responding to a secondary stimulus without the primary stimulus being presented.

In educational/instructional terms, the end-point in mental conditioning is described fully in Sargant's *Battle for the Mind* (1957). Sergeant enters into a discussion that centres on the fact that virtually any simple behaviour or response can be impressed on the human mind or learned by suitable conditioning.

2.1.3.4 J. B. Watson

In the development of learning theories, Watson inherited Pavlov's mantle as an extreme behaviourist. He demonstrated that conditioned responses could be imprinted and erased with continued experimentation and the reversal of the stimulus effect (Conditioning and Deconditioning). If a fairly traumatic response is induced when an attempt is made to satisfy a need, then the patient is conditioned to associate unpleasantness with the unacceptable need. Thus aversion therapy, one of the treatments for alcoholics, is based on Watson's work

Watson regards introspection as unscientific and consciousness as something beyond the scope of scientific investigation. To him, observable behaviour is the only study object of psychology, the method objective observation and the goal the study of the laws of stimulus-response connections. These connections are established by means of learning through conditioning. Watson (Watson & Rayner, 1920: 1-14) was unwilling to attribute any importance or value to instinct (inherited) or unlearned behaviour. In educational terms learning can be promoted by fear, but more effectively by controlled praise, effective feedback on performance and having students aware that they are under scrutiny.

In summary, therefore, the Behaviourists belong to the school of thought that learning focuses on content and is governed by three premises:

- an emphasis on conditioned reflexes as the element of behaviour and learning;
- an emphasis on learned rather than unlearned actions; and
- an emphasis on extrapolating human behaviour from observed and measured animal behaviour.

Behaviourist research continues to influence instructional practice through its emphasis on the learning of the content of specific subject matter, and on the acquisition of educationally desirable behaviour such as good study habits. Nonetheless, these theories of learning stop short of recognizing the importance of either the formation of concepts or problem solving.

2.1.3.5 B. Skinner

Skinner was pre-eminent as investigator of 'operant conditioning' and 'reinforcement of behaviour or actions' investigations. Gagné (1985: 9) explains that the concept of reinforcement of required behaviour is an essential part of Skinner's stimulus/response approach to learning (see Figure 2.1):

> ... the conception of reinforcement constitutes a control feature of his theoretical view of learning that does not necessarily depend on the notion of reward.

Figure 2.1 A specific response option that will become the preferred action

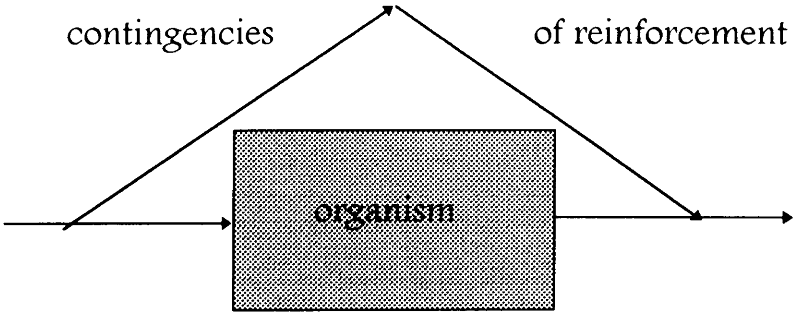
R1 Talking
R 2 Daydreaming
R 3 Reading → GOOD → praise
R 4 Writing MARKS
R 5 Revising
R 6 ....

This approach is radically behaviourist in the sense that Skinner concentrates only on explicit, observable stimuli and explicit, observable responses.

The radical Behaviourist tries to predict, through close observation, that certain responses will follow on certain stimuli and to specify what factors [mainly reinforcing contingencies] will increase and/or decrease the probability of specific responses. Thus the emphasis is an objective observation and there is little or no speculation on the individual's perceptions, thoughts, feelings and decisions related to response-change in reinforcing circumstances (see Figure 2.2 below).

Skinner regarded learning as a 'permanent change of behaviour', which is one of the principal aims of education whereby a student is 'taught' to think, feel, act in certain ways in response to specific situations.

Figure: 2.2 The generalized Stimulus Response cycle



According to Skinner (Hall & Lindzey, 1970: 482),

> ... in a functional analysis of behaviour there is no necessity to talk about mechanisms operating within the organism.

In an attempt to describe the way in which an individual acquires his/her behavioural [learned] repertoire, Skinner (1974: 149 & 167) says, for example:

> ... personality is at best a repertoire of behaviour imparted by an organized set of contingencies (reinforcing circumstances) ... .

He proposes the existence of both elicited and emitted [operant] responses to explain the observed behaviour without having to identify a specific stimulus that gives rise to every response (Miller, 1962: 372). Responses elicited by known stimuli are called 'respondents' and they lend themselves to direct study. On the other hand, the operants are responses emitted without any known stimulus. Skinner's main investigations have limited educational application because, as Miller (1962: 231) points out, they

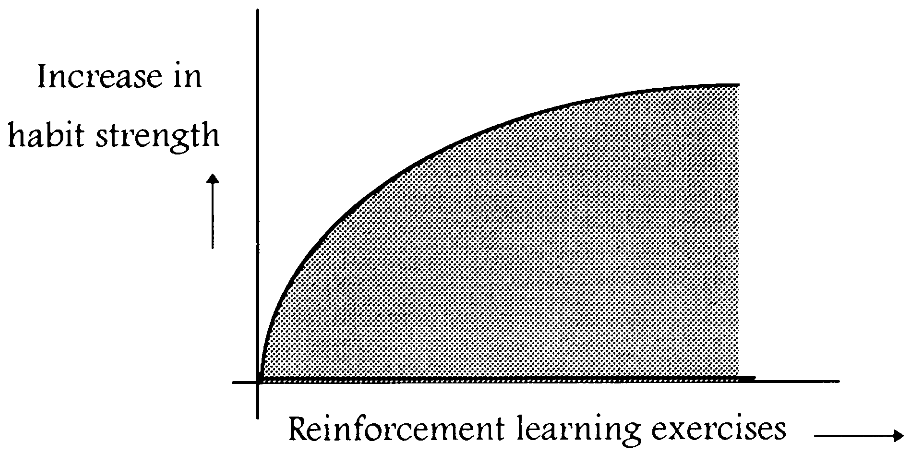
> ... did little to close the large intellectual hiatus between the single operant response [or even higher order responses] of a pigeon in a Skinner Box and the discursive intelligence of a modern, intelligent man.

2.1.3.6 C.A. Hull

In his description of the learning process, Hull refines Skinner's operant conditioning method. As Hall and Lindzey (1970: 426) explain, Hull's view is that the strength of a habit increases in accordance with the number of times that a stimulus and a response are contiguous in reinforcing circumstances. In other words, strength of habit is a function of the number of reinforced learning exercises. Hull's theory propounds that the increase in the strength of a habit takes place according to the law of diminishing returns (see Figure 2.3).

Hull's Drive Reduction hypothesis explains the reinforcement effect of a stimulus. These investigations by Hull are significant in education because they laid the foundations for the development of cognitive maps which permit behaviour/action and effect to be linked together (Tolman 1957: 364; Borger & Seaborne,1966: 71). These cognitive theories serve to draw attention to situations where 'understanding' is produced and this therefore has important ramifications for current classroom practices.

Figure 2.3 Hull's saturation of learning rates



By close observation of the performance of rats in mazes, Hull deduced that a rat will complete the correct route more and more rapidly the more often it is subjected to the trial. In a similar manner, the human brain can be trained to retain a sense of direction and position through repetition and reinforcement. In the classroom, this would be referred to as drill and routine exercises - such as the learning by rote of arithmetical tables and formulae or the repetition of basic scientific laws - that are used to reinforce material taught.

2.1.4 COGNITIVE PSYCHOLOGISTS AND COGNITIVE LEARNING THEORIES

Palrand and Lindenfeld (1985: 49) record a telling incident about attitudes to learning which underlines the dichotomy between the 'mechanical' and the experiential approaches to learning which, in turn, reflect the behaviourist as opposed to the cognitive approach:

> At age 14, a school girl asked her father something about Avagadro's number. Her father thought that he was explaining things nicely when she stopped him in obvious frustration and said, "Please, I don't want to understand. Just tell me what I've got to do!"

Reinforcing and up-dating this learning dilemma from a South African point of view, Professor Kieka Mynhardt of the Department of Mathematics, Applied Mathematics and Astronomy at UNISA (*Pretoria News*, 1996: 10) recounts:

> "Emphasis on Matric exams [*sic*] is not on knowing the basic stuff really well, it's on doing tricks," she said. "When I ask my students why they took certain steps in specific questions, they are not always able to give me a reason. The attitude is: 'We were taught to do it that way, that's why we do it that way'."

2.1.4.1 W. Köhler (Gestalt Psychology)

Parallel to the rise and dominance of behaviourism in the United States, a strikingly different school of thought concerning learning and behaviour was developing in Germany. This was the *Gestalt* School of Psychological thought based on problem solving situations. Although limiting his comments to Mathematics but equally applicable to the Natural Sciences, Bell (1978: 311) highlights the importance of problem solving in education:

> Problem solving is an appropriate and important activity in school mathematics [and science] because the learning objectives which must be met by solving problems and learning general problem solving procedures are of significant importance in our society.

For South African education the problems are compounded by the tendency to rely on rote learning. As an eminent South African chemist, Professor Tom Modro states (*Pretoria News*, 1996: 10):

> "Students are not focused on problem solving and are not used to independent thinking. ... Many students believe examinations involve regurgitating what they learned on the course. Students panic when they get an exam based on problem solving, even if it is simple. If you start memorising, then you are lost."

Köhler (1927) working, like many of the early theoreticians on animals, investigated learning in chimpanzees, in problem solving situations. He found that, in controlled test situations, chimpanzees enter into directionless trial and error activities and Köhler (Morgan, 1961: 275) then observed a moment of insight into the problem. The chimpanzees produced a solution to the problem facing them apparently without intermediate steps. A solution to a problem, for example, retrieving a banana beyond reach using a stick was, he observed, arrived at, 'at the moment of insight'. Köhler's work helps to define experiences referred to as 'Eureka' moments in solving problems. This instant insight or 'whole view' of the problem proved to be a substantial advance on other theories of learning.

Gestalt psychologists, such as Köhler, object especially to the elementarism of the psychology of the consciousness. They point out that any conscious experience is more than the sum of the component parts (Miller, 1962: 273). In a classroom, the Gestalt cognitive approach would require students to view the whole structure or development before fractionating it or breaking it into its component parts. In other words, as Olivier (1985: 37) points out:

> According to the most general definition of gestalt, the process of learning, of reproduction, of striving, of emotional attitude, of thinking, acting, and so forth, may be included as [the] subject matter of gestalt-theory in so far as they do not consist of independent elements, but are determined in a situation as a whole.

Thus the principles of Gestalt Psychology have greatly influenced not only researchers and theorists but also teachers in their emphasis on the individual's freedom rather than his/her determination by his/her drives or by circumstances; they emphasize that the individual's behaviour is aimed at objectives he/she sets for himself/herself rather than the causal influence of the past; they emphasize the uniqueness of the individual rather than the uniformity and regularity of all human behaviour; and they emphasize studying the total individual rather than merely aspects of his behaviour. In the performance assessment portion of TIMSS, students are expected to design experiments, manipulate materials, test hypotheses and record findings when completing a range of Mathematics and Science tasks - a gestalt mathematical and scientific experience evaluation.

2.1.4.2 H.F. Harlow

Harlow's investigations into learning 'sets' gave rise to the concept of 'generalized transfer' of learning. As Morgan observes (1961: 80-83), Harlow presupposed that prior learning speeded up subsequent learning in similar 'structured' situations. His experiments involved placing young monkeys in a series of choice situations and allowing them to learn to make the correct choices to uncover hidden food. Changing the cues from which choices had to be made resulted in correct choices being made more rapidly. It follows that, if well founded, learning can be transferred from a specific situation to a generalized situation. The classroom application of Harlow's findings depends on discovering what the students know before starting to teach a new material. Nearly two decades later, Ausubel (1963: 230), whose contribution to concept mapping is discussed more fully later in this chapter, was to express an extension of this approach succinctly as follows:

> Hence new material in the sequence should never be introduced until all previous steps have been thoroughly mastered.

Even later, the University of York's series of Chemistry class materials and guides, *Salter's Chemistry* (1981- ongoing) take cognizance of a prior learning assumption to new material, in that their teaching philosophy was, from a very early stage, encapsulated in the maxim: 'start where the student is at' (Lazonby: 1985). In the Salter's handbooks, the module or section instructions consistently begin with an injunction to the teacher to establish what the students know before proceeding with the content of the section. The additional innovative view of Salter's chemistry is stated by Waddington (1996: 9):

> The group has now developed an approach to teaching Chemistry to students based on three premises or realizations: Firstly, one has to stimulate the child's interest by using

examples they could relate to immediately [prior knowledge]. Context is essential. [The other two premises are not relevant to learning theory.]

The importance of a student's prior knowledge or what he or she brings to the classroom is an issue for some debate since prior knowledge, while providing a starting point for the teacher, also tends to be regarded as the origin of many misconcepts. However relevant prior knowledge is to the problem, as reflected by the students' background, it indubitably provides a sound basis for a 'consolidated start' when new material is taught.

Harlow's work can be regarded as a precursor to the study of Concept Development and Concept Attainment. However, his experimental work concentrates on problem solving and the attainment of insight; he offers no insight into how the learning of primary data and fact is processed and retained by the human brain.

2.1.4.3 A. Luchins

Luchins (1954: 272) engaged in problem solving studies that may have been seriously undervalued in current classroom practice. Building upon earlier theories, Luchins proposes that, in general, there are three routes to the solution of problems:

- Trial and error (cf. Thorndike),
- Rote or algorithm, or
- Perceptions of a problem and Insight (cf. Harlow).

Whilst Thorndike's trial and error theory may appear to be somewhat old fashioned, his studies are still descriptive of the way in which many students work. Although the rote and algorithm method may be regarded as being low level activities, Orton (1992: 29) cautions against discarding this method entirely:

> Learning mathematics is too much concerned with learning algorithms it might be argued, but can mathematics survive without them?

Reflecting Luchins's tripartite analysis, measurement for the TIMSS assessment of student achievement in Mathematics and Science involves written tests requiring students to perform a variety of tasks over the full range of intellectual skills including processing simple data, processing complex data, solving problem and constructing answers in a free response format. Luchins highlights one of the dilemmas of educators in South Africa today, that is, algorithmic versus insightful approaches in classroom teaching. The problem solving approach to Mathematics that is currently in the ascendant in South Africa (cf. Human, 1976; Noble, 1989: 24; Olivier, Murray & Human, 1992: 33-38) advocates insightful rather than algorithmic approaches to mathematical problems. It should be noted though that algorithms *per se*, are of themselves, not a faulty approach to problems unless they are applied as the sole unthinking approach to problems. The inability of students to achieve insightful answers to contextualized questions, which are not readily open to a conventional algorithmic approach, is referred to in Chapter 5 when examining the TIMSS outcomes for South African students.

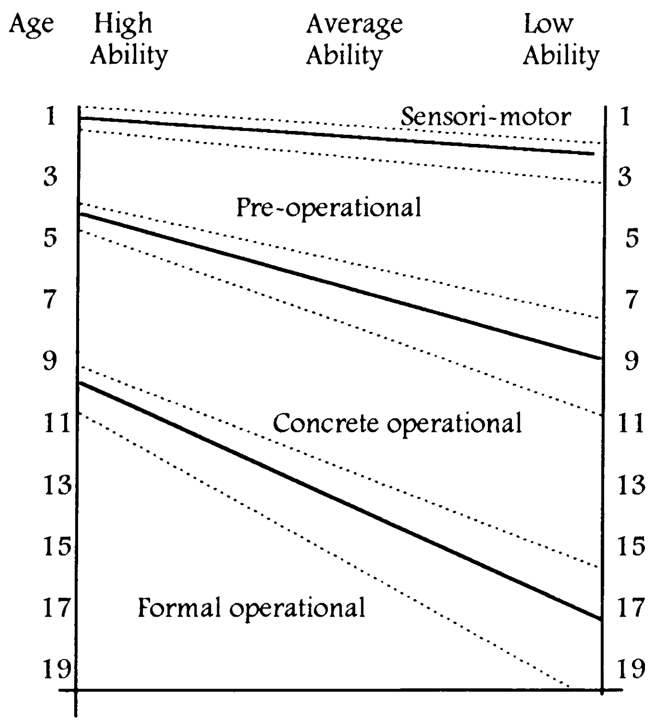
2.1.4.4 J. Piaget

From a lifelong dedication to recording observations of children, Piaget developed a theory that explains intellectual development from infancy to maturity. He proposes the following stages of intellectual development:

1. Sensori-motor stage - the concept of permanency of objects.
2. Pre-operational stage - acquisition of language - first concepts develop.

3. Concrete operational stage - manipulation of concrete objects and ideas.
4. Formal operational stage - able to deal with abstract thoughts and concepts. Development of symbolic systems.

Figure 2.4 Piaget's development phases



The boundary lines between the stages are, obviously, not fixed barriers or hurdles but represent the 'centre' line of a period of change or maturation.

In many ways children in Piaget's sensori-motor stage and the pre-operational stage are capable of learning that can be compared to behaviourist learning described by Thorndike and Skinner.

It can be postulated that many of the learning problems that students exhibit could be attributed to the school curriculum being out of step with the student's rate of maturation and the development of their conceptual abilities. For example, a student in the developmental stage of concrete thinking will not be able to cope with atomic theory. Atomic theory concepts demand a formal level of thinking. Much of the South African

Physical Science curriculum demands levels of cognitive development well in advance of the students' development to whom it is being taught (Gray, 1988 (a): 39-42). The same problem of the mistiming of presentation of material applies to Mathematics also. Orton (1992: 8) describes an American research report that states that the optimal time for a child to be learning division of fractions is twelve years and seven months. In virtually all curricula in South Africa (Department of Education, 1995 (e)) this arithmetic process commences a year earlier.

Students, who develop compensatory concrete perceptions of division of fractions early in their intellectual development, are likely to carry mathematical problems with them all their lives. Perhaps as a cover for this premature introduction to mathematical processes, teachers tend to rely on instructional algorithms rather than on ensuring that their students understand mathematical concepts. In many situations, misconcepts are formed and accepted by the student because he/she has not yet developed the intellectual capacity to manage the formal concept (cf. Driver, 1986; Jones, Palincsar, Ogle & Carr, 1987; Müller & Laing, 1987 and 1988).

2.1.4.5 Implications of cognitive development for mathematics and science

Whilst much attention has been paid to research into learning and evaluation and the teaching process itself, it seems that the considerations of cognitive development are seldom adequately considered when writing curricula for Mathematics and Science in South Africa today. Shayer and Adey (1981: 76) estimate that less than 35% of a population ever attain fully developed formal thinking and formal operational capacities.

In Piagetian terms, Mathematics and Science curricula, for all ability levels, feature many advanced formal concept topics. These curricula are so loaded with formal conceptual topics that the average learner requires extra assistance during or after formal classes.

2.1.4.6 R.M. Gagné and conditions affecting learning

Expanding on Piaget's theory of intellectual maturation, Gagné and Briggs (1974: 256) make an important contribution to the theory of learning and instruction in distinguishing between growth and learning:

> One part of the ability to learn ... lies in the human genetic makeup, and in an understanding of the process of development through growth. The other part, relating to a different set of circumstances in the life of the individual, is learning.

In these terms, growth is perceived as a natural event determined at birth by genetics whereas the factors that influence learning are determined largely by environmental factors such as experience and education, which is itself controlled experience. This has important implications for education: the manner in which educational experiences are delivered determines the quality and nature of learning. Learning is not simply an event that happens naturally; it is also an event that happens under certain observable conditions. Furthermore these conditions can be altered, controlled and understood.

Gagné's learning process requires:

- A learner;
- Events to stimulate the learner - a stimulus situation such as exposure to content, constructs, algorithms and concepts;
- Content that can be recovered from the learner's memory; and

- The learner's response to the input - performances and concept development.

Change in performance therefore indicates that learning has occurred. Notwithstanding Kriek's (1996: 49) contention that Gagné's learning theory is neo-behaviourist, Gagné's own stipulation of cognitive strategies as being one of the essentials for achievement would appear to modify this claim. Gagné (1985: 47) outlines the following requirements for achievement:

- Intellectual skills
- Verbal information (the student can repeat information
- in his own words)
- Cognitive strategies
- Attitude
- Motor skills

All these conditions are required and made use of for successful teaching and learning of Mathematics and Science. In fact, Gagné (1983: 11-16) earlier stipulates the specific application of the above requirements for the teaching of Mathematics when he notes:

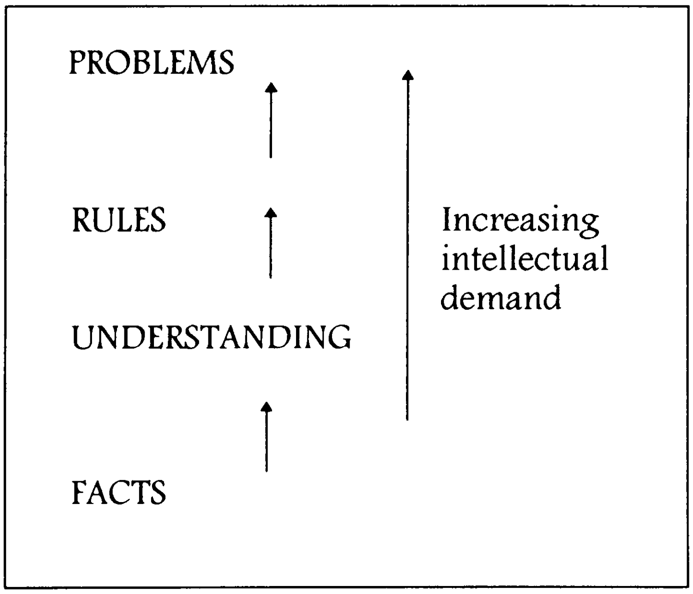
> A task analysis of the performance expected of a mathematics student would, I think reveal three major phases.

These phases, which apply equally well to Science, are

- Translating verbally described situations into Mathematics,
- The central computation phase, and
- validating the solution.

It follows that a new topic in either Mathematics or Science, encountered by the learner, is thus transformed or processed by the learner via a registration of material, followed by transfer to short term memory (computation phase in Mathematics, for example), and is ultimately stored in the long term memory for validation and concept formation.

Figure 2.5 A hierarchy of learning stages (adapted from Geer, 1993)



2.1.5 CONCEPT MAPPING

2.1.5.1 The Method

Concept mapping, following Harlow's prior learning theory, is a derivative of Ausubel's theory of a hierarchical memory or cognitive structure and of his principles of progressive differentiation and integrative reconciliation. More precisely, concept maps are a development of Ausubel's Advance Organizers which are used widely in modern textbooks. Novak and Godwin (1984: 625 - 645) coined the term 'concept map' and developed these maps as a tool intended to tap into the learner's cognitive structure and to externalize, for both the learner and the teacher to see what the learner already knows [and perhaps what is not known from the existence of voids and blanks and mislinkages].

As an instructional derivative of Cognitive Development, Cognitive Mapping can be used to provide insight into understanding how students or teachers think about their knowledge and how they regard that knowledge by developing a system for making it visual, that is by representing the conceptualization concretely.

Resnick and Resnick's definition (1990: 370) of a cognitive map is appropriate:

> A cognitive map is a graph/diagram consisting of nodes representing concepts and labelled directional lines denoting relations between the nodes.

Construction of Cognitive Maps is useful both as a diagnostic and as an assessment tool because they can provide insight into a student's higher order thinking.

A cognitive map constructed by a student can be regarded as a representation of his/her cognitive structures and mental connections. For example, for a chemist - a cognitive map is a long established tool to record and examine 'flow diagrams' in industry and/or chemical processes. Basson (1994: 50) illustrates the technique, where a cognitive map outlining the extraction of iron, is developed. A chemical equation can be the centre of a cognitive map - if the ramifications of chemistry are to some extent comprehended. In environmental science, food chains and food webs are practical exhibitions of cognitive maps in action.

Following the Resnick model (Resnick and Resnick, 1990), concept maps should be:

- Hierarchical (unless in the Associationist mode);
- Labelled with appropriate linking words;
- Cross linked to show relations and sub-branches.

Novak and Godwin (1984: 97) point out that new information/material is often related to and subsumable under a more general, more inclusive concept map. As a concept expands according to the principle of progressive differentiation, new concept nodes and new links are added to the hierarchy either by creating new branches or by differentiating [sub-dividing] existing ones even further. The networks of a concept may become increasingly more elaborate as the individual learns more and by linking new concepts to existing ones or, if the student is no longer able to integrate new concepts within his/her existing maps, new cognitive structures must be assembled.

There is some measure of controversy though as to whether cognitive maps can be interpreted as measures of cognitive structure; the issue is that students may not be aware of their own cognitive structures [unless their attention is drawn to them]. However, Basson (1994: 46-50) does make the point that cognitive maps are both a useful teaching tool and a useful learning method for the student.

Providing support for the efficacy of Cognitive Mapping, Ruiz-Primo and Shavelston (1966: 596) declare:

> ... the value of concept maps is based on the idea that understanding the "big" picture in any topic (mathematics or science for example) is very important and necessary not only to explore and create new things but to understand [more clearly] the existing world.

Current approaches to Cognitive Mapping do not seem to pay much attention to the correlation that this mapping concept appears to have with Gestalt Psychology. As mentioned earlier in this chapter, students should be directed to look at the whole problem before fractionating it. As such, Concept Mapping appears to have a strong relationship with the Gestalt appreciation of knowledge.

2.1.5.2 Applications of Concept Mapping

Uses for the Cognitive Mapping approach to 'a whole topic' could be applied to:

- Remedial training for Science teachers and their students who may not have an adequate holistic view of Science or a larger or smaller aspect of it.

- A learning aid for students - construction of a map as the teaching in a particular section progresses or starting with a topic map and shading sections as treated in class.

Concept maps are developed by listing relevant concepts and then drawing lines between them to represent important relationships. Development of cognitive mapping skills can be used by teachers and their students to assist in identification and treatment of even tenaciously held misconcepts. The instructional challenge seems to be in helping students to construct networks of meanings that are consistent with conventional Mathematics and Science.

2.1.6 LEARNING AND MISCONCEPTS

The problem of misconcepts is one which affects all Mathematics and Science teachers. Driver (1986) has played a leading role in developing a Constructivist approach to teaching in an effort to 'reconstruct' the scientific misconcepts that students develop.

Less able students, faced with conceptual changes that they cannot readily absorb in terms of their own world view, are often in situations where they accept a 'classroom' concept in the classroom and return to the outside world retaining their own conceptual explanations and values. As Krathwohl *et al.* (Gagné, 1977: 240) observe:

> A widely held view of the relationship of attitudes and values is that the former may be arranged on a continuum that represents increasing degrees of internalization ranging from those that lightly held to those that are strongly valued and therefore highly resistant to change.

Chapter 4 of this thesis examines the level and type of misconcepts as they are illustrated in the TIMSS findings. Such strongly held misconcepts are extremely difficult and time consuming to correct. Students will manoeuvre themselves into a position where they will repeat what the teacher wants. As Jones *et al.* (1987: 80) state:

> Misconceptions are generally ideas that are reasonable and appropriate in a limited context, but students inappropriately apply them to situations where they do not work.

Misconceptions are thus understandings that arise from daily life and experience, or compromises that are made, with an understanding which does not retain validity in conditions of rigorous testing and examination.

Research in a number of countries, including South Africa, has been carried out on the paradox that appears to exist between concepts and misconcepts dealing with topics such as electricity, mechanics, chemical equilibrium and atomic theory (Johnstone, 1986: 60; Müller & Laing, 1987: 58; Schneider & Smith, 1986: 10; Stanton, 1990: 32). Despite these obvious curricula shortcomings there appears to be little overt evidence that cognitive development is part of curriculum committee considerations. This present study attempts to elucidate this problem in the discussion of South African TIMSS results (see Chapter 5).

2.2 FACTORS AFFECTING LEARNING IN SOUTH AFRICA

The series of three articles by Arons (1983: 576-581; 1984 (a): 21-26; and 1984 (b): 88-93) serve to point out the routes to, and benefits of rational teaching of subjects with a high level of concept content. These articles also serve to underline the shortcomings and problems of teaching methods employed in South Africa. Underlying each of the three articles is the use of verbal and written communication to explain and consolidate content and concepts.

2.2.1 LEARNING AND LANGUAGE PROBLEMS

Essential to Arons's approach is a dialogue between teacher and student that deals with concepts systematically and from varied intellectual approaches. However, it has been noted in documents, such as *The Provision of Education in South Africa* (Human Sciences Research Council, 1981) and the University of Stellenbosch study on language mastery (Odendaal, 1985), that both teachers and students often lack mastery of the English language for effective teaching and learning to take place. Odendaal investigated the language mastery of a substantial number of teachers in KwaZulu through the application of a graded reading and writing test. The results are presented in Table 2.2 below.

Table 2.2 Teacher competency in reading and writing skills.

Band or Level of Proficiency	Reading Test Frequency N = 333	%	Writing Test Frequency N = 333	%	Combined proficiency N = 333	%
1						
2	4	1.2				
3	2	0.6				
4	15	4.5	3	0.9	10	3.0
5	65	19.5	90	27.0	86	25.8
6	155	46.5	198	59.4	191	57.3
7	69	20.7	35	10.5	33	9.9
8	16	4.8			1	0.3
No response	7	2.2	333	100.0	333	100.0
Band Mean	6.16		6.10		6.14	
Total	333	100.0	333	100.0	333	100.0

(N = number in sample) (Odendaal, 1985: 35)

(Band or achievement level 8 (highlighted) was regarded as the minimum language mastery required for a Higher Primary School teacher.)

Odendaal's (1985) statistical presentations indicate the extent of language problems; and in spite of their being somewhat dated, there is little reason to suggest that these figures are not applicable to South African schools a decade later, particularly to underprivileged teachers and students. The TIMSS findings in this regard are discussed fully in Chapter 6 of this study.

2.2.2 LEARNING AND READING PROBLEMS

In her research study conducted for the University of New Jersey, Gionfriddo (1985) examines the readability of three successive editions of a seventh and eighth grade textbook. This is particularly relevant as these two Grades form the TIMSS Population 2 test sample in South Africa. Her principal finding was that as the readability age level of the textbooks was reduced, students performance improved. However, as Gionfriddo (1985: 2) finds '... students faced with texts that are too difficult for them often gain little information from their reading'. This presages Odendaal's comments on the reading accessibility of texts for students, discussed below. It can be presumed that difficulties in reading and comprehending the TIMSS question papers was a contributory factor to the South African national performance.

Odendaal (1985: 44) is also informative about the inaccessibility/ accessibility of textbooks to students for whom they are targeted. The table below shows some of the findings.

As Odendaal (1985: ii) observes:

> ... in many cases, pupils enter secondary school with very little English. Because pupils cannot communicate in English, teachers who, in many cases have an inadequate grasp of English themselves, frequently resort to mother tongue, particularly in subjects other than English.

Maja (1994) and Jansen (1993) make the point though that in many schools the teacher's mother tongue may not be the students' thus handicapping the student still further.

TABLE 2.3 Students' ability to understand textbooks

Subjects in which students claim not understand their textbooks	% of respondents who did not understand their textbooks
Science	65.8
Geography	62.5
History	60.4
Mathematics	32.1
Health Science	32.1
Agriculture	25.8

(Odendaal, 1985: 46)

The basic problem was not so much the degree of difficulty of the content as the lack of language proficiency for teachers and students whose mother tongue is not English (see also the discussion in Chapters 6 and 7 dealing with decoding and comprehension of text). Barnard (1989: 1), in his study of Mathematics teaching and learning, reinforces Odendaal's findings:

> Pupils who do not understand the vocabulary will not benefit from the teaching [of Mathematics].

Barnard too highlights the point that this is not a new problem to Mathematics education, in particular, when he quotes De Wet (1961: 50-51):

> Language is very important in the formation of concepts because pupils use it [language] to increase the effectiveness with which they acquire [and apply mathematical] concepts.

An assertion that can be deduced from the above studies is the foundation of a large number of problems in teaching and learning Mathematics and Science stem primarily from the basic language problems of both teachers and learners.

Apart from the complexity of Mathematical and Scientific language, Orton 1992: 128) raises issues of the semantic value of words. For example, he cites a situation where a class was posed the question,

> What is the difference between 47 and 23?

To a mathematician, 'difference' is the verbal or printed signal for subtraction. Student responses, however, varied from, 'One is bigger than the other'; to 'One number is about twice the other number'. In a mathematical sense these answers are incorrect but in a semantic sense they cannot be regarded as entirely inappropriate. This language difficulty is compounded when learning is filtered through the medium of a second language working on problems 'for no apparently useful reason' (Berry, 1985 in Orton, 1992: 143).

Compounding basic second language problems is the fact that Mathematics and Science both have specialized vocabularies. Some of these subject-specific words are technical and once the definition is understood, they should present no real problem; others, however, have a Mathematics and Science contextualized meaning as well as other meanings, as seen in Orton's observations on the word 'difference' illustrated above.

An important area of research in the field of learning and teaching Mathematics and Science lies in how students, taught in a language other than their mother tongue, actually approach problems. This raises a number of issues: Do they attempt the problem in the language in which it is presented? Do they mentally translate the problems and then translate the process and answers back into the language of testing? Although not pertinent to the present study, answers to such questions should provide valuable insights into education in South Africa.

2.2.3 LANGUAGE AND PROBLEM SOLVING

Although they pre-date TIMSS by over a decade, the Arons' papers prefigure the problem of the student breakdown in the Mathematics sections of TIMSS in that he (1983: 577) argues convincingly that,

> Without practice in giving verbal interpretations of calculations, students take refuge in memorizing patterns and procedures of calculation.

Arons (1983: 577) provides several extended examples - one of which serves to emphasize the importance of spoken and written language mastery:

> "Suppose we go to a store and find a box costing $5.00 and containing 3kg [of the material we require]. What is the meaning of the number 5.00/3?" Some students will say "How much you pay for 3kg" but, in this more familiar context, many will recognize that we have calculated how many dollars we pay for one kg. (The former group is in need of further dialogue, using more concrete examples, before a correct response can be found.) One can now try to get the students to the generalization that in such situations the resulting number tells us "How many of these (in the numerator) are associated with one of those (in the denominator)."
>
> If one then asks "in the case of the box costing $5.00 and containing 3kg, suppose we now consider the number 3/5.00. In the light of what we concluded in the previous example, does this number have an interpretation or is it meaningless?" Many students, including ones who initially gave the correct interpretation of 5.00/3, now encounter difficulty. Some revert to earlier patterns of incorrect statements. Others consider the number meaningless.

In such instances, there seem to be two difficulties superimposed:

> a) Although the students may previously have been given opportunity to calculate or think about 'unit cost,' i.e. how much we pay for one kg. they very rarely if ever have been asked to think about the inverse - how much material one buys for $1.00.
>
> b) 5.00$/3kg involved dividing a larger number by a smaller one. To many students this is more intelligible and less frightening than the fraction represented by 3kg/5.00$.

The presentation of this concept, assumed to be in the learning range of Standard 6 students, clearly illustrates the need for a relatively sophisticated level of language mastery which may not have been attained by either the students or the teachers where there is the association of units with numbers.

Arons (1983: 577) continues his discussion with another highly relevant observation which develops an earlier comment on rote learning:

> Many students have very great difficulty giving such verbal interpretations since they are never asked to do so. Without such practice in many different contexts, students do not think about the meaning of the calculations they are expected to carry out, and they take refuge in memorizing patterns and procedures ... rather than penetrating to an understanding of the reasoning.

This summation exemplifies, in illustration of the two main approaches to learning outlined earlier in this chapter (see 2.1.1), much of what happens in many South African classrooms where the dominant mode of learning and problem solving is a reliance on algorithm, recipe and memorized procedure. Avoidance of this reliance is unlikely to happen save in the most exceptional circumstances and tends to be reinforced and compounded by large classes, the architectural constraints of closely packed bodies in classrooms that are too small (Gray, 1995: 1-4) and the inability, whether from cultural training or through authoritarian inclination, of the teacher to make the transition from content based approaches to the more demanding concept formation and problem solving approaches by entering into discourse with his or her students.

2.2.4 COMPREHENSION OF THE WRITTEN WORD

One of the propositions of this study is that lack of achievement in Mathematics and Science may relate as much to the problems of language as to the memory and conceptual problems intrinsic to these subjects. Despite the shortage of textbooks and other printed material, teachers have been shown to rely on text books more than on lesson preparation (Gray, 1991: 34). If teachers are not able to fully comprehend a printed text, successful teaching and learning is unlikely to take place. Similarly, students working through the medium of a language not competently mastered are unlikely to develop suitable reading habits. It follows that they will therefore be unable to record class notes efficiently or to learn effectively or to use that information.

2.2.5 LANGUAGE AND TIMSS

There is considerable evidence, particularly from the Free Response Items in the TIMSS test papers, that suggests that language problems represent a handicap although there is no means as yet available at this time to assess the magnitude of this handicap. It should be remembered that almost 80% per cent of the responding sample answered the TIMSS tests and questionnaires in a second or third language. The language problem is compounded by the lack of books in the home environment and the general reluctance of students to read (Sander, 1993). The statistical findings of the TIMSS achievement tests and questionnaires in the context of students' first and second languages is discussed more fully in Chapter 6 as already noted.

2.3 FINDINGS FROM PREVIOUS IEA STUDIES

2.3.1 HOME LIBRARIES

SIMSS found that there was a high correlation between achievement and the number of books in the students' homes. TIMSS, South Africa, suggests that in the majority of South African homes books tend not to be a common feature and they do not exist in sufficient numbers or variety to provide valuable enrichment so as to optimise intellectual growth by means of language mastery. This factor is discussed more fully in Chapter 6. On the same basis, the effectively world wide pattern of reduced achievement shown by rural students also relates to their limited exposure to

Mathematics and Science through their contact with these concepts in the Mass Media, books and every day scientific experiences.

2.3.2 TIME SPENT IN TEACHING AND LEARNING

2.3.2.1 'Time on Task' constraints to learning

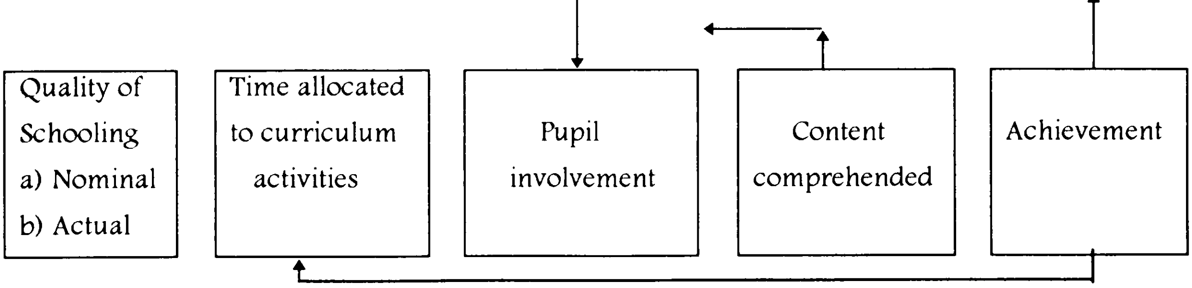
'Time on task' considerations were one of the significant findings in SIMSS. National achievement correlates highly with effective schools hours. In the research milieu this statement can be corroborated. Bennett (Entwistle, 1987: 82) underlines the point that not only is 'time on task' necessary for successful teaching but also for optimal time management.

> The lower ability pupils can learn more by having less taught to them, and having it taught redundantly to the point of over learning (i.e. repetitively, proceeding in small steps they can master without cognitive strain).

For less able students [or less confident ones] Orton describes Bennett's approach to successful mathematics teaching as being 'little and often' with a reinforced feedback loop. However, this approach to teaching is time consuming and also requires delicate judgement in its use as there are counter indications, as discussed below.

The management model that Bennett (Entwistle, 1987: 82) proposes follows:

Figure 2.6 A proposed time management model



This is one of the most obvious and critical factors that determines whether and to what extent learning takes place. SIMSS recorded a significant correlation between both the length of the school year and achievement and the number of class hours per week spent on Mathematics and Science and achievement. The intensity with which these subjects are taught and achievement also correlate closely. In the South African situation this matter of time on task becomes a crucial factor in any discussion concerning achievement. The personal comments from teachers, experience with TIMSS in the field and comments from the HSRC Schools Needs Survey all suggest that too little time is allocated to Mathematics and Science, too many school hours are missed in the school term and in many schools Mathematics and Science are not taught by Mathematics or Science trained teachers. Further discussion of time on task follows below and, in an international context, it is commented on in Chapter 6.

2.3.2.1.(a) Short days

A large number of schools start late and often close early. During the process of TIMSS, field operators often found local idiosyncratic practices of half days on occasions and extended breaks.

2.3.2.1.(b) Short terms

During the school visits made by TIMSS test administrators, many schools appeared to suffer from delayed time-table production at the beginning of a school term and delayed registrations of students. Late receipt of textbooks and other equipment compounds these problems so that effective teaching was often not implemented until the third or fourth week of a school year.

2.3.2.1.(c) Short years

The normal school year in Japan (a high achieving nation in the TIMSS achievement tests) is usually two hundred and thirty days. The school year in the United States, which did not rank highly in SIMSS, is often less that one hundred and ninety school days. The South African school year, in he late 1980s was usually 202 - 204 school days. In 1995, the school year was reduced to one hundred and ninety-eight school days and this was reduced even further by a number of politically determined school holidays for the electoral process to take place. Extrapolating from the SIMSS findings, the limited time available for teaching did not bode well for South African achievements in such testing programmes as TIMSS even before the programme was implemented.

2.3.2.1.(d) The overall effects of lost time

In the South African situation, lost time for one or a combination of reason/s may reduce available teaching time to as little as 50 per cent of that scheduled for specific subjects in many schools (TIMSS, 1994-1995; HSRC School Needs Survey, 1994-1996). At present, South African education is plagued by inefficiency, serious language problems, inadequately qualified teachers and poorly motivated students and teachers in the critical fields of Mathematics and Science. Didactic considerations notwithstanding, improved time management and efficiency alone would contribute significantly to the rather poor record of achievement in the majority of South African schools.

2.4 CHAOS THEORY - AN APPLICATION OF THE STUDY OF DYNAMICAL SYSTEMS

In concluding this development and description of learning theory the recently developed field of mathematical CHAOS THEORY (Devancy: 1985) is of interest. This theory pertains to widely differing fields of study such as astronomy, fractal mathematics, stock-broking and computerized recognition of hand writing (Mendel & Fu, 1970: 287).

Elementary Chaos Theory assumes that it is not possible deal with an unlimited amount of data distributed over a multitude of parameters however, patterns are identifiable. Rather than attempting to make sense of all the data and all the parameters, Chaos Theory instead examines the vast array of information for localized and more generalized patterns.

In learning theory and investigations into the process of learning, there is a vast amount of available data as well as a multiplicity of observations. Although the Behaviourist school and other schools of learning have successively been superseded, it seems unwarranted and dismissive to claim, as do Novak and Godwin (1984: xi) that:

> For almost a century, students of education have suffered under the yoke of the behavioural psychologists, who see learning as synonymous with change in behaviour. We reject this view, and observe instead that learning by humans leads to a change in the meaning of experience.

For example, patterns of learning theory data that 'fit' each of the succession of behaviourist theories can be discerned. It appears though that all theories are correct in that, all theories fit, to some extent, and serve to explain a greater or lesser range of observations/patterns. Equally all may be regarded as having limitations, since within the vast data array of learning theory experiments, observations and findings, none can fit more than large patterns in the data array. It seems possible that the common mistake that learning theorists have made is to assume that they are developing a universal truth and seek to explain all learning. This is just not possible unless all learning theories can be reconciled into a 'Universal Theory'. There is perhaps no 'unified' theory of learning waiting to be unveiled. However, as learning theory research progresses, the patterns in the 'chaos' will become more and more identifiable and more inclusive of the processes and situations they can satisfactorily explain.

2.5 SUMMARY OF IMPORTANT IMPLICATIONS OF LEARNING AND TEACHING THEORY FOR MATHEMATICS AND SCIENCE EDUCATION

The main proposition of this chapter is that the historical range of learning theories is particularly relevant to Mathematics and Science teaching; and that, for convenience, these theories can be divided into two general categories, *viz.* those following the Behaviourist school of thought which, in essence, treat Mathematics and Science as factual disciplines; and those propounded by the cognitive/insightful school of thought which approaches these two focuses from a problem solving, concept formation point of view.

This chapter has also attempted to show that there is a symbiotic relationship not only between learning theory and teaching practice, but also between the two schools of thought detailed above. This is especially so in the case in the teaching of Mathematics and Science which seeks to give practical application to the pedagogic principles arising from these theories. This is primarily because these two disciplines share comparable scientific bases as do theories of learning.

Gagné (1977: 145), for example, highlights the importance of the principle of 'prior learning' (see 2.1.4.2) to success in further learning and conceptualization, discussed in this chapter, when he declares that

> ... readiness for learning any new skill is conceived as the presence of certain relevant subordinate intellectual skills.

And Middlekamp & Kean (1988: 53) endorse the point when they quote a student's informal observation that,

> To solve problems, we have to learn all that other stuff.

In terms of the problem solving theories of learning dealt with in this chapter, the wisdom of this seemingly ingenuous remark becomes apparent in Claxton's assertion (1984: in Orton, 1992: 24) that,

> The whole of cognition may be said to be a study of memory.

Claxton's more erudite statement, in turn, underlines the interrelationship between the two broad approaches to Mathematics and Science teaching outlined in this chapter and as noted above. That learning theories, which play such a crucial role in successful teaching, should therefore be treated - as they have been in this part of the thesis - diachronically (historically) as well as synchronically (contextually, hierarchically and at a particular point in time) to show their development and evolution is testified by Ausubel's caution (1968: 3) about isolationism in learning theories:

> It would be wrong to tie rote learning too closely to the behaviourist approach and by implication suggest that it has no place within a cognitive approach. There is, after all, the eclectic view, that children do need to develop their own understanding from within, but that there might be a very firm place for practice, and even perhaps for some element of rote learning.

This chapter has argued that a knowledge of learning theory and how students learn and make use of the knowledge imparted to them remains a central action of education and it is particularly necessary for teachers to be aware of the potential of their classes to achieve the aims of the curriculum through a sound knowledge and understanding of the theories of learning examined in this chapter.

One of South Africa's top scientists, already quoted, Professor Kieka Mynhardt (*Pretoria News*, 1996: 10) also makes a plea for the specialized training of Mathematics and Science teachers when she asserts:

> "They don't need to just train teachers in science and mathematics, they need to train them differently. ... You need more teachers who have more than a first degree in science."

Implicit in this injunction to train Mathematics and Science teachers 'differently' lies a call for the need for mastery of subject content, knowledge of didactic methodology and an understanding of the theories of learning for these specialist subject teachers.

CHAPTER 3

THE CONTEXTS Of MATHEMATICS AND SCIENCE EDUCATION IN SOUTH AFRICA

3.1 THE EDUCATION ENVIRONMENT OF TIMSS IN SOUTH AFRICA

3.1.1 INTRODUCTORY REMARKS

In describing the frame of reference for this major international investigation into Mathematics and Science education which, as argued in Chapter 1, is unique to South Africa in terms of its scope and magnitude and its focus on achievement in education, this chapter is intended as a record of the education environment of late 1995 since the findings, which are now a matter of historical record, can be better appreciated when contextualized.

Then, as now, South African education was in a state of flux. South African education could, at that stage, and still can be compared to the development of a butterfly. Before the elections in 1994, South African education was in a 'larva' stage, and in an extension of the metaphor, this was an ugly caterpillar phase, with eighteen administrative segments. In the present 'pupa' stage, change is endemic within a political framework of reconstruction and it is not possible to predict the beauty, or lack of it, in the butterfly (or moth) that will emerge in the coming years. The then 'new' Government of National Unity and all political parties made forceful policy statements about education and its reform being high on their respective priority lists (cf. ANC, 1994 (a); Department of Arts, Culture, Science and Technology, 1994; and Department of Education, 1995 (a)).

In the context of these affirmations concerning the importance of education, Mathematics and Science were and still are recognized as particularly important school subjects. However, as the momentum for change increases, current academic reporting on education faces the certain risk of not being able to keep pace with the rapid progress in science and technology, a dilemma inherent in the 'running on the spot' analogy noted in the opening paragraphs of Chapter 1. In other words, educational assessments in Mathematics and Science quickly become an historical record rather than a 'blue-print' for a way forward.

Furthermore, in spite of the anticipated priority to be placed on Mathematics and Science, the problems facing both administrators and educators in South Africa are, like those of the learning process discussed in the preceding chapter, compounded by their own internal processes. As mentioned in the discussion on the pedagogy of learning in Chapter 2, the varieties of learned capabilities presuppose what has been learnt thus far (see, for example, the comments on prior learning [2.1.4.2]). The fundamental problem in South Africa (as is also discussed in the previous chapter), like that in most developing countries, is that of literacy. In South Africa, the literacy question is aggravated by the complexities of the language of instruction. In fact, the language problem is regarded as so significant in the South African context, both in terms of instruction and its impact on assessment, that further brief commentary is made later in this chapter.

Any evaluation of achievement in education must be viewed in terms of the socio-political climate within which the testing took place. Apart from the educational problems, each country that participated in the Third International Mathematics and Science Study had its own particular context and its own peculiar problems that both the testing procedure and the outcomes reflect. For example, the Russian Federation was in the midst of civil war in Chechnia; in Israel the 'intefada' prevented testing in the Arabic schools; in Colombia the civil disturbances surrounding the 'drug wars' impacted on TIMSS access to schools; in Australia there was a 'teachers' strike' in New South Wales; and in Switzerland two of the cantons refused to participate. For convenience, the South African context is divided into physical and demographic factors, on the one hand, and administrative factors, on the other. This latter aspect is more important in terms of the argument of this chapter.

3.2 COUNTRY PROFILE

3.2.1 GEOGRAPHICAL CONTEXT

The Republic of South Africa occupies the southern portion of the African continent bounded by Namibia (to the North West), Botswana, Zimbabwe, Mozambique and Swaziland. The Kingdom of Lesotho is an enclave. The area of South Africa is 1 220 088 square kilometers. Distances make the uniform application of testing instruments exceedingly difficult given the facts that large areas are virtually inaccessible by road and that both electronic and postal communications are either inefficient or non-existent. Thus there is a geographical context of a large country with poorly distributed natural resources such as water and a relatively poor communications system. These factors, in themselves, serve to compound other constraints under which TIMSS - South Africa was conducted.

3.2.2 POPULATION

3.2.2.1 Demographic distribution

The population of South Africa just over 39 000 000 (Central Statistical Bureau, 1991) and, as is characteristic of most developing countries, there are serious concerns about the population drift from the rural areas into the cities. South Africa's population is rapidly becoming urbanized, which not only places an added strain on amenities but also, and more significantly, in terms of this research project, further complicates the problems of providing an adequate education for all. The main destinations of this drift are Durban in KwaZulu-Natal and the industrial heartland in, and surrounding Johannesburg in the province of Gauteng, areas in which the plethora of informal settlements and the derivative political and social disturbances did little to facilitate a testing programme.

3.2.2.2 Distribution of wealth

Yet another problem is the fact that the South African population is also characterized by wide discrepancies in the distribution of wealth, and so of opportunities for advancement in education, which is a costly investment for those living at subsistence level, as well as for improvements in conditions of living, which impact on a student's ability to learn. The school and home environments in which South African students learn were investigated as an adjunct to the TIMSS achievement test via a questionnaire, the findings of which are discussed in Chapter 6 of this study. As also illustrated in the data on the Wealth of Nations presented in the opening chapter, wealth and achievement correlate significantly.

3.2.2.3 Population growth

Rapid population growth, both natural and immigrant (legal and illegal), is another cause for concern as the government attempts not only to meet the basic safety needs of the individual to security, stability and order (Morgan, 1961: 492), but also to address the growing demands for housing, employment, health services and education, perceived as constitutional rights (Government Gazette, 1994: 8-18).

3.2.2.4 Multiculturalism and multilingualism

With its multicultural population, South Africa is, with good reason, referred to as the 'Rainbow Nation' (Tutu, 1994). Each sector has its own cultural ideology and therefore its own distinctive cultural aspirations. Although cultural diversity need not necessarily be the catalyst for confrontations in the classroom, such diversity did compound the problem of the compilation of non-culture specific testing instruments.

By contrast to the mostly unilingual or bilingual countries that participated in this international Mathematics and Science achievement study, there are eleven principal languages in South Africa and a number of minor ones. The dominant eleven are now recognized by the constitution, the mass media and by the State as official languages. This profile is itself aggravated by the realities of history. Historically, the population has been classified as tripartite: black (80 per cent from nine main language groups), white (14 per cent: 8 per cent of which are Afrikaans speaking and 6 per cent English speaking), Indian (3 per cent) and coloured (4 per cent, which includes people of mixed race, and descendants of the Malay slaves most of whom speak Afrikaans) (Central Statistics Bureau, 1995).

3.2.3 LANGUAGES AND ASSOCIATED EDUCATION PROBLEMS

Insofar as the application of TIMSS is concerned, which in South Africa was offered in the two languages of instruction: English and Afrikaans, just under 80 per cent of the sampled students answered the tests and questionnaires in a language other than their mother tongue. That is, the mother tongue was not English or Afrikaans, which are legislated as the official languages of instruction in South Africa from Standard 3 [Grade 5]. Very few countries, if any, are in this situation. Hong Kong, for example, evaded the issue of bilingualism by presenting TIMSS tests and questionnaires in both English and Cantonese, the mother tongues of the bulk of the population (Law, 1995).

What must be acknowledged is that over and above the TIMSS intellectual expectations of mathematical and scientific knowledge there is, within the test instruments and questionnaires, a substantial expectation of functional literacy which had the potential to present serious problems for South African students. Following Perkins (1992 : 112), what this suggests is that languages of thinking display a cultural bias:

> ... education is as much a process of acculturation as of learning particular pieces of knowledge. To achieve thoughtful learning, we need to create a culture of thoughtful learning in the classroom. This is a matter of how teachers talk to students, students to teachers, and students to one another. And talk here is of course a matter not just of the words used but of manner and style and goals [and protocols and culture].

Odendaal's (1985) investigations into language problems in education, discussed at some length in Chapter 2, are still relevant. Fundamentally, Odendaal (1985: 10) states that second language acquisition occurs through both a subconscious and a taught/learned process; and she asserts that neither process is effective in South Africa. Odendaal confirms that the learning process is interdicted in the event of a breakdown in communication between the teacher and the student. This interdict becomes magnified when the teacher also has a limited control over the language of instruction.

Poor language control problems are perpetuated by students, poorly equipped linguistically, gaining entrance to tertiary education and thence returning to the classroom as inadequately trained teachers to recycle the communication problems. Odendaal (1985: 12) highlights the fact that,

> ... the teacher is the most important classroom variable

and as a consequence this leads to serious problems in Mathematics and Science education.

Literacy is not the focus of this study; however, research in this topical field is of great relevance to the problems of Mathematics and Science achievement in view of the fact that learning these subjects may be impeded by language problems as noted above, in Chapter 2 (cf. de Wet, 1961; and Barnard, 1989: 1) and in Chapter 6. The rationale behind the present study lies higher up the educational hierarchy. It is located in one sense in the fact that South Africa has an obligation to develop the potential that already exists in order to ensure economic growth and continual scientific and technological development. In this context, the target groups identified for the TIMSS study should already

- have had the privilege of a basic education,
- possess a degree of literacy,
- have reached a certain level of education (at least Standard 5)

and therefore should have had sufficient foundation and language mastery to provide the base on which to build this investigation.

Deetlefs, Norton, Steinberg, Suttner & Witthaus (1991:7) state that UNESCO distinguishes between a 'basically literate' person as one,

> who can with understanding both read and write a short simple statement on his every day life,

and a 'functionally literate' person as one who is

> ... able to engage in all those activities in which literacy is required for effective functioning of his group and community and also for enabling him to continue to use reading, writing and calculation for his own and the community's development.

It is this particular definition of basic literacy which is important to TIMSS as it articulates the *a priori* assumption for successful outcomes in Mathematics and Science assessment.

3.2.3.1 Literacy levels

Tuchten (1994: 3) provides current statistics on the illiteracy rate in South Africa which suggest that 15 000 000 South African adults, not to mention children, have not completed primary school and thus cannot cope with the demands of a modern industrialized economy. Tuchten's survey (1994), in fact, finds that of all the children entering schools in South Africa between 1970 and 1990, more than half (55 per cent) dropped out before they reached Standard 5. Counter opinions though claim that the functionally illiterate population is closer to 9 000 000 (Barry, 1996) which is still a significant proportion.

3.3 THE BACKGROUND TO EDUCATION IN SOUTH AFRICA

In an attempt to formulate an education policy for post-apartheid South Africa in the spirit of reconstruction and development, Deetlefs *et al.* (1991: 9) argue that forty years of 'apartheid' and the 'Bantu Education System' have deprived the vast majority of South Africans of what is now a 'fundamental human right', largely because of poverty, lack of schools, and a method of education which, according to them, effectively

> ... discouraged the development of critical, logical and problem-solving skills.

There are, of course, a multiplicity of factors, other than 'apartheid' and 'Bantu Education', that have militated against a sound education for all. Not the least of these additional factors are the matters of drop-out rates and the low achieved literacy rates, mentioned above. Other factors, such as urbanization, immigration, multiculturalism and multilingualism have also already been touched on; while yet others, such as stay-aways, school violence, chalk-downs, lack of finance, poor management and/or maladministration, lack of facilities as well as lack of properly qualified facilitators (that is, underqualified and undervalued teachers) form part of the on-going discussion in the rest of this chapter. The governance of the country, as well as of education, are core issues.

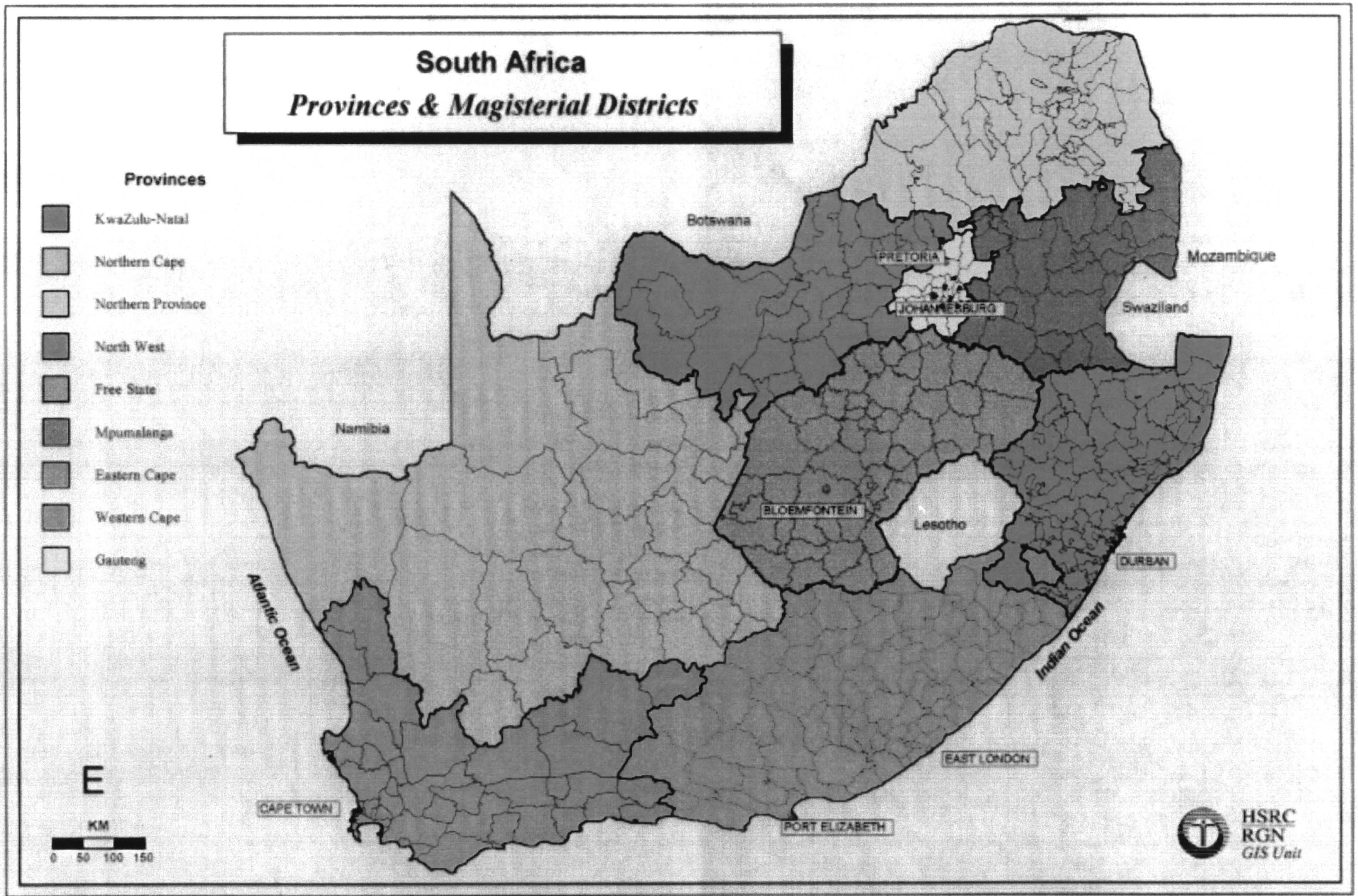
3.4 ADMINISTRATION AND STRUCTURE OF THE EDUCATION SYSTEM

3.4.1 GOVERNANCE IN EDUCATION

As noted above, in terms of the Constitution, education is a provincial responsibility; and, in the 'new' South Africa, each of the nine provinces has a department responsible for education, with the national Department of Education forming the umbrella body. These are:

- the national Department of Education
    - Eastern Province
    - Gauteng Province
    - KwaZulu/Natal
    - Mpumalanga Province
    - Northern Cape Province
    - Northern Province
    - North West Province
    - Free State Province
    - Western Province

(See also the map over the page.)

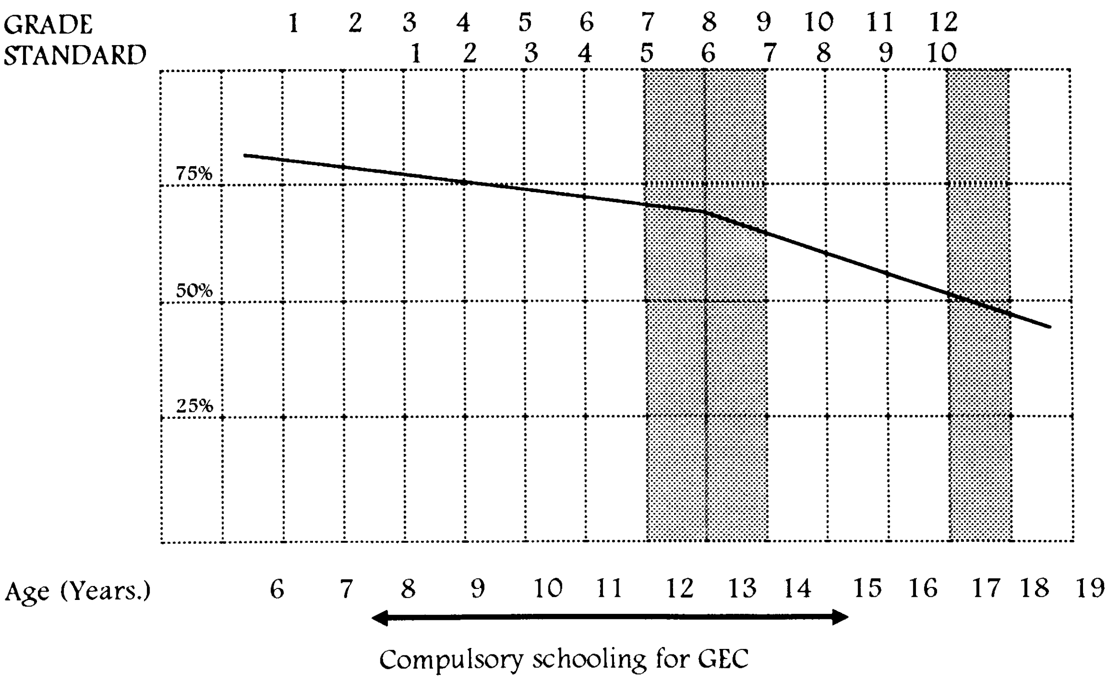

South Africa
Provinces & Magisterial Districts
Provinces
KwaZulu-Natal
Northern Cape
Northern Province
North West
Free State
Mpumalanga
Eastern Cape
Western Cape
Gauteng
Botswana
Mozambique
Swaziland
Namibia
PRETORIA
JOHANNESBURG
BLOEMFONTEIN
Lesotho
DURBAN
Atlantic Ocean
Indian Ocean
EAST LONDON
CAPE TOWN
PORT ELIZABETH
E
KM
0 50 100 150
HSRC
RGN
GIS Unit

All of the provinces are in the throes of reforming the eighteen previous education administrations into unified provincial education administrations. In the Northern Province, for instance, this involves the merging of portions of no less than eight pre-existing authorities into a single administrative unit. The TIMSS programme required regular communications with all of these new administrative structures.

3.4.1.1 Compulsory education

Another aspect of governance in education is the question as to whether education is to be compulsory or voluntary. Within the new Education Act (Department of Education, 1995 (c)), provision is made for education to be compulsory and free for the first nine years (the General Education Certificate level [GEC]) and thereafter voluntary and possibly fee paying to Grade 12 (Further Education Certificate [FEC]).

Figure 3.1 Enrolment in schooling - 1993 (RIEP, 1994; TIMSS, 1997)



School attendance control is made difficult by the existence of a highly mobile population (already alluded to) and political and social violence in the poorer areas and in informal settlements. This latter factor leads to students attending schools in 'quieter' areas, often far from the parents' home. When the administration of the TIMSS testing was planned, the anticipated application was based on 1993 enrolment data (see Figure 3.1 above).

3.4.1.2 Education enrolment statistics

In this context 'education statistics' refers to student enrolment. A number of factors affect the lack of clarity on exact enrolment figures, not least of all the problems of drop-out rates referred to earlier and illustrated in Figure 3.1, which are particularly difficult to monitor in a social climate of minimal cooperation. Enrolment figures thus contain a degree of uncertainty. The latest available consolidated figures, provided by the University of the Orange Free State, Research and Manpower Development Unit (RIEP, 1994) are given in the figure below.

A further comment on enrolment, with specific reference to Mathematics and Science is, for convenience, made at the end of this chapter.

The student enrolment data provided in Figures 3.1, above, and 3.2, below, broadly represent overall enrolment in schools at the time of the TIMSS testing in South African schools. The most recent RIEP report (1996: 10) provides a breakdown of enrolment at the various school Standards/Grades for 1995 shown in Figure 3.3 below.

Figure 3.2 Student enrolment - 1994 (SSA [Grade 1] - Std 10 [Grade 12]) by population group :

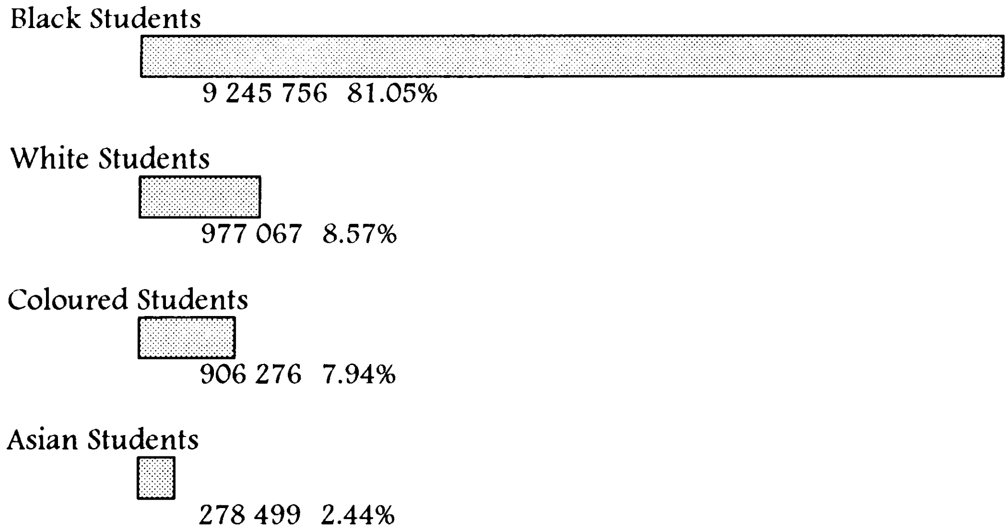
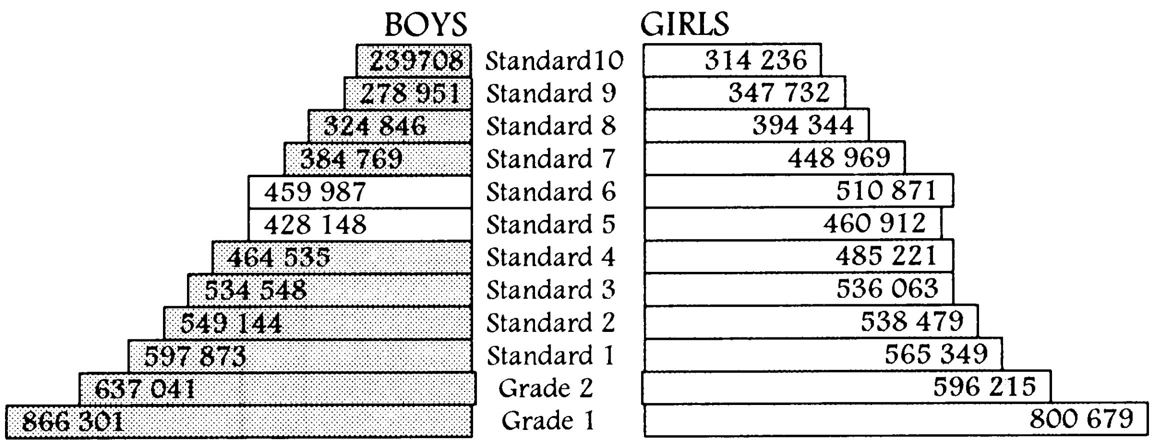


Figure 3.3 Estimated school and class enrolments for 1995

[The year groups that TIMSS tested are shown unshaded.]



The enrolment for Standard 6 on the national totals is, like the majority of the provinces, higher than Standard 5. A possible reason might be a massive return to school of learners who originally left school after Standard 5 and are now returning. Figures 3.1, 3.2 and 3.3 above provide an overall picture of the South African education system and the rate at which drop-outs occur. These figures also provide an indication of the attrition process that takes place between school years.

However, there was little reliable information available concerning the percentages of participation for the start of the 1996 (January) year.

3.4.1.3 Participation and non-participation in schooling

With the former absence of compulsory schooling for much of the population there has been a wide range of entry age in South African schools. Problems are compounded by numbers of students repeating classes. For example, 24 per cent of Standard 10 students attempted to register to repeat the class in January 1996 (Department of Education, 1996 (a)). In some provinces it has been estimated (Nieuwenhuis, Gray, Mmabolo & Moutlana, 1992: vii) that there were regions where the number of students repeating years was not inconsiderable and approximated to the number of school-age children not in school.

An investigation undertaken by Quigley (1990: 101) into the reasons for non-participation and drop-out for Canadian Indians is of some relevance to the current South African situation even though his study concentrates an Adult Basic Education programmes. Quigley's research indicates that many learners who reject formal education are capable learners and that it is the entrenched normative values and cultural systems which they resist and not the acquisition of knowledge. It can be argued that these findings apply to students of all ages and a wider range of developing cultures. In fact, the ideological thrust of Quigley's argument is precisely that which informed the Black Consciousness movement and the 'struggle' in South Africa. Other arguments against education uncovered in Quigley's study (1990:105) that are particularly relevant to the South African situation are, for example, that it preserves 'the values of the middle class'; and that while 'empowerment' has been a major goal of literacy programmes since the 1960s, in reality it often merely furthers

> the ends of national development and the entrenchment of an elitist social order.

Similar 'empowerment' philosophies may be said to underpin the current South African belief of 'Mathematics and Science for all' irrespective of cost and consequence. An important value of the TIMSS achievement testing will be to reveal the potential for success or lack thereof if this philosophy develops into practice.

The administration of education in South Africa can be further subdivided into the broad category of management and planning.

3.4.2 MANAGEMENT AND PLANNING

3.4.2.1 Responsibilities for the curriculum.

Curricula are at present being developed by forty-one national subject curriculum committees consisting of Government representatives, Non-Governmental Organization representatives, recognized experts and teachers (Department of Education, 1995 (a)) who would benefit from an examination of the TIMSS findings and the selection of suitable international role models such as the Czech Republic, Thailand or Malaysia. It has been noted (van Rensburg, 1996) that in the general climate of administrative uncertainty the activities of these subject committees are somewhat hesitant. It is of interest that the national core curricula were revised to some extent in 1993 as an interim measure to match the government's requirements of equity in education. The Mathematics and Science curricula, however, underwent little change in this revision process.

3.4.3 STRUCTURE OF THE EDUCATION SYSTEM

3.4.3.1 The structure of the South African education system.

In 1995, at provincial level, some provinces had still not constructed middle management organigrams and were operating on an agency basis making use of staff from the previous education structures.

3.4.3.2 Grade range of schools

In most cases South African school system is divided into four phases:

- Junior Primary - Grades 1 to 3
- Senior Primary - Grades 4 to 6
- Junior Secondary - Grades 7 to 9
- Senior Secondary - Grades 10 to 12

For administrative and practical purposes, Grades 1 to 7 are normally grouped together in primary schools and the higher grades, 8 to 12, are in secondary schools. It should be remembered, however, that for a large number of rural and 'Farm Schools' this conventional division is anything but typical. In the North West Province and Eastern Province, the schools are divided into three levels, primary schools, Grades 1 - 6, middle schools, Grades 7 - 9 and senior secondary schools, Grades 10 - 12. Several other combinations of grades in schools also occur; for example, some primary schools go up to Grade 8, while others may stop at Grade 6, or show other peculiar class ranges. It is odd factors such as these that made administration of TIMSS, which targeted Grades 7 and 8, difficult.

Figure 3.4, below, illustrates the relation between the levels of education and their equivalence levels (Department of Education, 1994(b); Centre for Equivalence of Education Qualifications, 1995). The educational levels of three TIMSS populations studies are indicated in the same figure.

3.4.4 TYPES OF SCHOOLS

Another aspect of structure concerns the types of schools in South Africa already alluded to in Chapter 1 of this thesis. Primary schools tend by and large to be 'comprehensive' and non-specialist. By far the majority of South African secondary level schools are also what are more commonly called Comprehensive Schools. Middle Schools, spanning Standards 4 to 7 were policy in what became the North West Province. Middle Schools also existed in fewer numbers in the Eastern Province. The other provinces have records of a few Middle Schools but they were never a widely implemented policy. There is a limited range of specialist schools that provide commercial subjects, technical subjects and a few specialist schools that provide art, music and ballet as specialties. There are also a number of Technical Colleges offering a wide range of vocational and pre-vocational instruction. Somewhat surprisingly, however, in a country that depends for its survival on training scientists, technologists and technicians, there are effectively no specialist schools for Mathematics, Science and Technology.

Private schools exist but at the present time find themselves under considerable political and social scrutiny and pressures. Some of these are denominational in character (Roman Catholic, Anglican, Jewish and Muslim for the most part) and place emphasis on religious instruction but in general even these 'privileged' schools do not place a priority on Mathematics and Science instruction.

Figure 3.4 A schematic of the South African education system

PUPIL AGE	YEAR	SCHOOL STANDARD	TECHNICAL COLLEGE		TEACHER TRAINING	TECHNIKON LEVELS	UNIVERSITY LEVELS
24						T6	Doctorate
23					B.Ed. degree	T5	Masters degree
22					Higher Education Diploma	T4	Fourth Year Hons. or Engineering deg.
21					Education Diploma	T3	Third Year B Degree}
20			N6			T2	Second year
19			N5			T1	First year
18	12	Standard 10	N4	TIMSS POP 3			
		Senior Certificate (FEC)	N3				
17	11	Standard 9	N2				
16	10	Standard 8	N1				
15	9	Standard 7					
14	8	Standard 6		TIMSS POP 2			
13	7	Standard 5		TIMSS POP 2			
12	6	Standard 4					
11	5	Standard 3					
10	4	Standard 2					
9	3	Standard 1					
8	2	Grade 2					
7	1	Grade 1					
6	Minimum admission age to Formal Schooling						
5	Pre-school/Nursery school/Kindergarten						

3.4.5 SCHOOL OPERATIONS

3.4.5.1 The school year

The school year, already alluded to in Chapter 3 (see 2.3.2.1), approximates to two hundred school days. There were supposed to be one hundred and ninety-eight school days in 1995 but in actual fact there were fewer because of non-scheduled public holidays and unofficial stay-aways. The school year starts in the first or second week in January and ends early in December. There are short vacations in April (two to three weeks), July (usually at least four weeks) and in early October (two weeks). Schools terms and holidays are a matter of Provincial concern and determination. As will be pointed out in Chapter 7, one of the findings of the Second International Mathematics and Science Study [SIMSS] was that, in general, achievement relates directly to the length of the school year and instructional hours in the classroom. For example, the length of the United States School year is in the order of one hundred and eighty-five school days whereas the Japanese school approximates to two hundred and thirty days. The Japanese achievements in SIMSS far exceeded the USA performance. This distinction between school years appears to be a valid predictor as similar findings recur in the TIMSS study.

3.4.5.2 The school week

The school week is normally Monday to Friday with a large number of what can be called idiosyncratic features such as 'a half day on Wednesdays' or similar 'unofficial' recesses which contributes to the 'time on task' problem discussed later.

3.4.5.3 School hours

The hours of instruction are nominally from 07.30 to 13.30 or 14.00 depending on the free/break times scheduled. A large proportion of schools do not function for more that four hours per day due to late starts, early closing and student or teacher absences. The erratic functioning of South African schools is one of the major problems that has been identified (for example, Jansen, 1993: 84 *et seq;* SABC TV News bulletin, 23 January 1997 - Member of Gauteng Education Committee) but has yet to be seriously addressed.

3.4.5.4 Time allocated to Mathematics and Science

Class time allocated to Sciences and Mathematics varies from two to four hours per week each, but the effectiveness of this time allocation is varied. Expressed as a percentage this ranges from 7 to 15 per cent each for Mathematics and Science although in many schools there is an added time allocation given to Mathematics.

3.4.6 CLASS SIZE AND STUDENT/TEACHER RATIOS

Class size and teacher/student ratios are currently political issues. Class size in primary schools may range from twenty-four to sixty, and classes of ninety or more are on record. Secondary school classes tend to be somewhat smaller, especially those classes (Grade 10 and beyond) in Mathematics and Science since enrolments are generally lower for these subjects since they become optional at this level. There is the political intention that a target of forty-two students per class in primary schools and thirty-five students per class in secondary schools should be achieved. Even this policy is complicated by the existence of what were referred to as 'Model C' schools which were supported by fees paid by parents to augment staffing quotas. These schools have now been legislated out of existence as enclaves of privilege (*Pretoria News*, untitled.1996).

3.5 CERTIFICATION OF MATHEMATICS AND SCIENCE TEACHERS

3.5.1 MATHEMATICS AND SCIENCE TEACHERS

The training of Mathematics and Science Teachers is carried out in the provincially maintained Teacher Training Colleges which issue three and four year diplomas. The eighteen universities are concerned with Mathematics and Science teachers training at a postgraduate level. With the development of a free South African industrial base - career opportunities away from the uncertainties of teaching have become, even at this early stage, an attractive alternative. Training and certification of teachers is currently a matter of intense political and professional debate. Major changes in the characteristics of Teacher Training are anticipated during 1997. A recent departmental publication 'Norms and Standards and Governance Structures for Teacher Education' (Department of Education, 1994 (a)) is still being debated. In these proposals there are requirements for courses in General Science/Environmental Science, Mathematics and Technology for all junior and senior primary teacher trainee courses.

3.5.2 IN-SERVICE TRAINING

Teacher In-service Training and upgrading is not a requirement except in the case of occasionally organized courses arranged by Education Department officials. In two or three of the provinces there are teachers' up-grading units with full timetables. In other provinces these courses are the responsibility of the Teachers' Centres or handed over to Non-Governmental Organizations [NGOs].

3.6 MATHEMATICS AND SCIENCE CURRICULUM AND PEDAGOGY

3.6.1 GOALS OF THE MATHEMATICS CURRICULUM

Table 3.1 Goals of the Mathematics curriculum (Department of National Education, 1990)

TIMSS POPULATION 2. (Grade 8)	TIMSS POPULATION 3. (Grades 10-12)
1. Societal Aims This syllabus is aimed at fostering and developing the following societal aims:	1. Societal Aims This syllabus is aimed at fostering and developing the following societal aims.
1.1 to work towards the reconstruction and development of South African society and the empowerment of its people;	1.1 to work towards the reconstruction and development of South African society and the empowerment of its people;
1.2 to develop equal opportunities and choice;	1.2 to develop equal opportunity and choice;
1.3 to contribute towards the widest development of the society's cultures;	1.3 to contribute towards the widest development of the society's cultures;
1.4 to encourage democratic, non-racial and non-sexist teaching practices;	1.4 to encourage democratic, non-racial and non-sexist teaching practice;
1.5 to create an awareness of and a responsibility for the protection of the total environment.	1.5 to create an awareness of and a responsibility for the protection of the total environment.
2. General Teaching and Learning Aims	2. General Teaching and Learning Aims
This syllabus is aimed at fostering the following teaching and learning aims:	This syllabus is aimed at fostering the following teaching and learning aims.
2.1 to develop independent, confident and self-critical citizens;	2.1 to develop independent, confident and self-critical citizens;
2.2 to develop critical and reflective reasoning ability;	2.2 to develop critical and reflective reasoning ability;
2.3 to develop personal creativity and problem solving capabilities;	2.3 to develop personal creativity and problem solving capabilities;
2.4 to develop fluency in communicative and linguistic skills e.g. reading, writing, listening and speaking;	2.4 to develop fluency in communicative and linguistic skills e.g. reading, writing, listening and speaking;

2.5 to encourage a co-operative learning environment;	2.5 to encourage a co-operative learning environment;
2.6 to develop the necessary understanding, values and skills for sustainable individual and social development;	2.6 to develop the necessary understanding , values and skills for sustainable individual and social development;
2.7 to understand knowledge as a contested terrain of ideas;	2.7 to understand knowledge as a contested terrain of ideas;
2.8 to contextualize the teaching and learning in a manner which fits the experience of the pupils;	2.8 to contextualize the teaching and learning in a manner which fits the experience of the pupils.
3. Specific aims of Mathematics Education	**3. Specific aims of Mathematics Education**
The syllabus is aimed at fostering and developing the following specific aims of mathematical education:	The syllabus is aimed at fostering and developing the following specific aims of mathematical education:
3.1 to enable pupils to gain mathematical knowledge and proficiency;	3.1 to enable pupils to gain mathematical knowledge and proficiency;
3.2 to enable pupils to apply mathematics to other subjects and in daily life;	3.2 to enable pupils to apply mathematics to other subjects and in daily life;
3.3 to develop insight into spatial relationships and measurement;	3.3 to develop insight into spatial relationships and measurement;
3.4 to enable pupils to discover mathematical concepts and patterns by experimentation;	3.4 to enable pupils to discover mathematical concepts and patterns by experimentation;
3.5 to develop a number sense and computational capabilities and to judge the reasonableness of results by estimation;	3.5 to develop a number sense and computational capabilities and to judge the reasonableness of results by estimation;
3.6 to develop the ability to reason logically, to generalize, specialize, organize, draw analogies and prove;	3.6 to develop the ability to reason logically, to generalize, specialize, organize, draw analogies and prove;
3.7 to enable pupils to recognize a real world situation as amenable to mathematical representation, formulate an appropriate mathematical model, select the mathematical solution and interpret the result back in the real world situation;	3.7 to enable pupils to recognize a real world situation as amenable to mathematical representation, formulate an appropriate mathematical model, select the mathematical solution and interpret the result back in the real world situation;
3.8 to develop the ability to understand, interpret, read, speak and write mathematical language;	3.8 to develop the ability to understand, interpret, read, speak and write mathematical language;
3.9 to develop an inquisitive attitude towards mathematics,	3.9 to develop an inquisitive attitude towards mathematics,
3.10 to develop an appreciation of the place of mathematics and its widespread applications in society.	3.10 to develop an appreciation of the place of mathematics and its widespread applications in society.

3.11 to provide basic mathematical preparation for future study and careers; 3.12 to create an awareness of and an appreciation for the contributions of all peoples of the world to the development of mathematics.	3.11 to provide basic mathematical preparation for future study and careers; 3.12 to create an awareness of and an appreciation for the contributions of all peoples of the world to the development of mathematics.

It noticeable that the goals set for the Mathematics curricula both at Standard 7 (Grade 8) level and for the final three years of school (Upper Secondary) are identical. This would appear to be a serious flaw in the conceptualization of the age/development determined goals that should be established for Mathematics education.

3.6.2 AIMS OF THE SCIENCE CURRICULUM

Table 3.2 Aims of the Science curriculum (Department of National Education, 1992) - Standards 5-7.

AIMS

1. To provide pupils with the necessary subject knowledge and comprehension, i.e. knowledge of the subject as science and as technology;
2. To develop in pupils the necessary skills, techniques and methods of science, such as handling of certain apparatus, the techniques of measuring etc.;
3. To develop in pupils the desirable scientific attitudes, such as interest in natural phenomena, desire for knowledge, critical thinking etc.;
4. To introduce pupils to the scientific explanation of phenomena;
5. To introduce pupils to the use of scientific language and terminology;
6. To introduce pupils to the applications of science in industry and in everyday life.
7. To help pupils obtain perspective in life, for example to develop a reverence for the Creator and an esteem for the wonders of the created universe through contact with the subject matter.

It is left to the teachers to specify the objectives for each topic and lesson. This implies that the specific objectives are related to specific subject matter, methods and evaluation.

3.7 MATHEMATICS AND SCIENCE PEDAGOGY

When considering classroom practice it must be remembered that there is a substantial hiatus between intentions/aims and what actually happens. A Mathematics or Science teacher faced with a large class (perhaps as many as seventy students) cannot always operate on what are generally regarded as good classroom techniques and call upon the resources of learning and teaching theory to transmit content and understanding. These problems are compounded by inadequate classrooms which are too small for the numbers they are expected to accommodate, insufficient desks and chairs and often inadequate ventilation in hot climatic conditions. Many classes in fact, in the Northern Province, are held outside under trees. One of the consequences of overcrowding is that teachers confronted by large classes tend to transfer text to the blackboard for the students to copy into their books (see the discussion on the student questionnaires in Chapter 6). This system promotes a response of rote learning which perpetuates the stultification of thinking and problem solving skills. Laboratory equipment is usually absent, unused or inadequate. Replacement of laboratory consumables and breakages does not usually take place (TTA evidence to the Investigation into Education, Volume 13, 1980).

3.8 NATIONAL ENROLMENT IN MATHEMATICS AND PHYSICAL SCIENCE CLASSES

3.8.1 THE PROPORTION OF STUDENTS STUDYING MATHEMATICS AND PHYSICAL SCIENCE

The proportion of each grade cohort enrolled in one or more Mathematics of Science course/s is extremely low. Nominally Mathematics and Science or Environmental Science are compulsory subjects at the primary level and up to Grade 9. However, this situation is clouded by the lack of qualified teachers, already referred to, and the failure of the Colleges of Education to enrol and graduate sufficient teachers in these subjects. In many cases the teachers who teach these subjects are teaching them irrespective of their qualifications and even their interests.

Only Physical Science and Biology as science subjects are offered as optional subjects beyond Grade 9. Mathematics is an optional subject at this stage also. A very small fraction of students offers Additional Mathematics and even fewer students (restricted to a few of the established private schools) offer a thirteenth year in Mathematics/Science subjects. (Neither UNISA nor the Private Schools association were unable to provide precise figures for enrolments in a thirteenth year of schooling.)

Mathematics and Physical Science are not subjects of preferred choice. In the case of Physical Science slightly over 15 per cent of the total number of students opting for this subject in Standard 8 offer it for examination in the 12th Grade for the School Leaving Certificate (see Figures 3.6 and 3.7 at the end of this Chapter. This data was supplied by the Department of Education - 1995(f)).

Both Mathematics and Physical Science were examined at Higher Grade, at Standard Grade and at Lower Grade until fairly recently. (Lower Grade was discontinued as a school subject in 1994.) The level at which a student makes an entry tends to be a decision made as late as possible. Many students enter Higher Grade in the hope of being awarded a 'condoned' pass at Standard Grade (Nieuwenhuis *et al.,* 1992: xii).

Data concerning the gender distribution of examination entries in Mathematics and Physical Science classes is not available but it is commonly recognized that there is a serious imbalance in enrolments particularly in Mathematics and the Sciences.

3.8.2 Low enrolments in Mathematics and Physical Science

Since Mathematics and Physical Science are commonly regarded as being the 'killer subjects' they receive, in Standards 8 to 10 [Grades 10 to 12], low entries. Only relatively small proportions of students enter these subjects for the final School Leaving Certificate examinations. Up to Standard 7 [Grade 9] Mathematics, General Science or Environmental Sciences are a component of the core curriculum and all students study these subjects.

3.9. THE OUTCOMES OF MATHEMATICS AND PHYSICAL SCIENCE EDUCATION

Figures 3.5 and 3.6 (Department of Education, 1996 (c)) appended to the end of this chapter and, as mentioned above, depict poor outcomes from Mathematics and Science education. The input numbers of students to these courses is low and the output of successful students is substantially lower. In terms of the Wealth of Nations discussed in the opening chapter of this study the prognosis for South African education being able to provide the technological and scientific manpower required for the future is bleak.

The immediately notable features of the charts on the following pages are

- The proportion of Standard 10 [Grade 12] students entering for the Physical Science school leaving certificate examination is low. (Less than 50% for the 'white' population and only 15 per cent for the black population.)

- The pass rate for the black students is particularly low.

- Even for those 'underprivileged' students who obtain passes in Physical Science it is known that the symbol distribution is not good. (Top symbols such as 'A's and 'B's are remarkably rare.)

- Appreciably fewer females offer Mathematics at School Leaving Certificate level and even fewer offer Physical Science.

The South African School Leaving Certificate entries and results obtained in Mathematics and Physical Science are not satisfactory and the outcomes of the TIMSS investigation do not any degree of optimism for short term future improvements unless drastic measures are undertaken. This poor performance is particularly alarming in view of the interdependence of academic achievement in Mathematics, Science and Technology and economic prosperity as pointed out in Chapter 1.

3.10 SUMMARY

This chapter has attempted to provide an impression of the school environment and the general state of education in South Africa at the time of the TIMSS testing in schools (1995), within the broader framework of geographical and administrative contexts. Just over a year and a half after the TIMSS testing much of education is still in flux; new publicized policies are still being implemented and the Departments of Education are still in the process of establishing themselves.

Figure 3.5 Participation and success rates in Mathematics and Physical Sciences at Grade 12.

OF EVERY 100 pupils writing Standard 10 Examinations in 1993

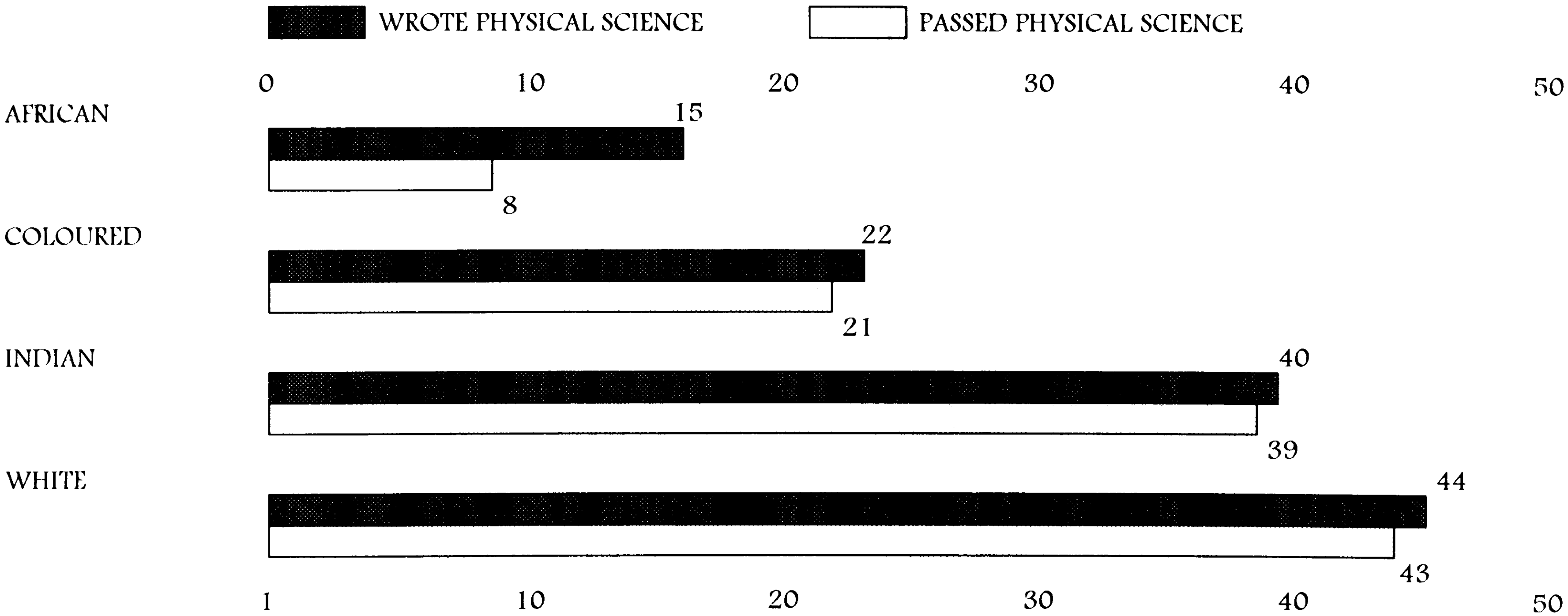
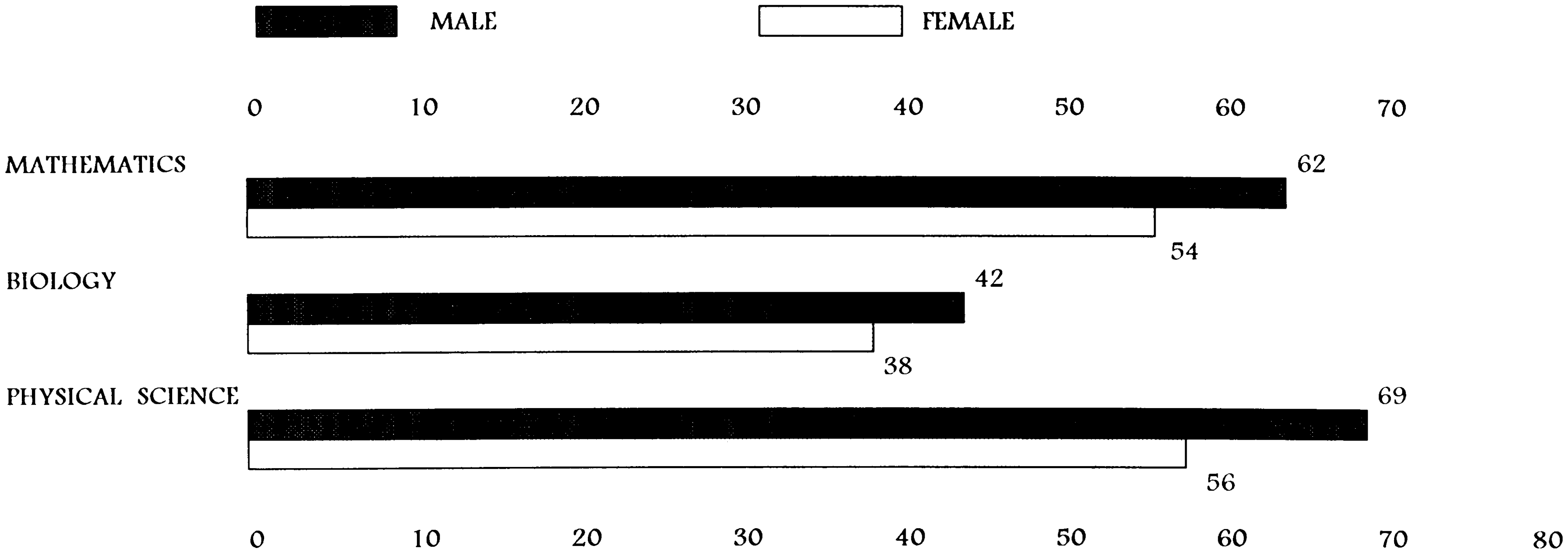


Figure 3.6 Percentage pass rate by gender and by subject



CHAPTER 4

THE TIMSS STUDY DESIGN

4.1 THE SIGNIFICANCE OF TIMSS AND ITS RELATION TO THE AIMS AND OBJECTIVES OF THIS THESIS

Since the release of the results of the Third International Mathematics and Science Study, on 24 November 1996 (*Sunday Times*: 1), the country has witnessed an increasing awareness and an ongoing debate about the state of Mathematics and Science education in South Africa.

4.1.1 THE PRIMARY AIM OF THIS THESIS IN RELATION TO TIMSS

The preceding chapter examined, in some detail, the South African milieu for the application of TIMSS; and, in line with the primary aim of this thesis (that is, to obtain a realistic view of South African Mathematics and Science achievement in an international context compared with more developed and less developed countries (see 1.1.2.2)), Chapter 3 also ventured to suggest the reasons for South Africa's participation in what is described in the TIMSS International 'Fact Sheet' (TIMSS, 1996 (a): 1) as

> The largest and most ambitious international study of mathematics and science achievement ever undertaken.

In his National Press Release on 26 November 1996, the President of the Human Sciences Research Council (Stumpf, 1996: 2) implicitly concurs with this view of TIMSS, succinctly pointing to the significance of this study to South Africa:

> This is the first international study to measure the achievement levels of South African students as a whole.

TIMSS was one of a number of recent initiatives undertaken to assess the current state of the country's scientific and technological standing. These initiatives include a national audit of personnel resources in Science and Engineering currently being carried out by the Department of Arts, Culture, Science and Technology and regular surveys carried out by professional associations such as the South African Chemical Institute. The present chapter is an attempt both to describe the instrument used to assess the Mathematics and Science achievement of some 500 000 students from forty-five countries around the world, and to interpolate the problems encountered in the application of this instrument in South Africa.

4.1.2 ONE PREMISE IN RELATION TO TIMSS

As stated in Chapter 1, a fundamental premise that this thesis seeks to examine is:

- That the South African education system is not educating students in Mathematics and Science to the achievement standards of other developing countries that participated in TIMSS.

The *a priori* assumption is that South Africa needed and still needs innovative new mechanisms to measure its performance and so to offer baseline information to assist the current restructuring of its Mathematics and Science education systems. Foregrounding a 'national system of innovation', the Department of Arts, Culture, Science and Technology (1996: 4) quotes the *Report of the Auditor-General of Canada* (1994), first, to highlight the centrality of innovation:

> Innovation has become a crucial survival issue. A society that pursues well-being and prosperity for its members can no longer treat it as an option;

and then, to capture the essence of its vision for Science and Technology in South Africa:

> ... an innovative society is willing and able to discuss and examine openly all issues, even controversial matters and "sacred cows"; it retains the suppleness to explore and experiment; and it has the wisdom and persistence to pursue selected options in the quest for desirable results. It is able to envision a desired future, examine its possibilities, select preferred results and pursue its choices.

And, as already intimated, TIMSS is one such innovative gauge seen as appropriate for the evaluation of national scientific performance.

4.1.3 OTHER AIMS OF THIS THESIS IN RELATION TO INNOVATIONS SUCH AS TIMSS

The above excerpt precisely reflects a number of the other aims of this thesis (see 1.1.2.2), which bear repeating in the present context:

- to derive a prognosis for South Africa's economic development as it may be influenced by the outcomes of the current education system;

- to identify, at a national level, the successes and weaknesses in teaching and learning Mathematics and Science; and

- to explore a variety of opportunities that exist to upgrade attainment levels in Mathematics and Science.

4.1.4 FEATURES OF TIMSS

4.1.4.1 Inputs and outcomes

If education is to be effective, a balance must be found between innovation and cost. As the then Canadian Prime Minister, Mulroney, noted prior to the Canadian Auditor General's comment (1989: 3):

> Second only to Sweden, Canada spends more money on education than any other country in the world. And education is just not delivering the goods.

In the African context, it is arguable that South Africa might be emulating the Canadian experience of 'not delivering the goods' in education; and for this reason it is of importance to examine inputs relevant to outcomes in its present education system, in part, through TIMSS.

4.1.4.2 The complexity of TIMSS

Because of the very nature of the TIMSS study and the involvement of a large number of countries, each with its own characteristics and conditions for education, the TIMSS programme was of necessity a complex exercise, both in its design and in its execution.

4.1.4.2.(a) Teachers, students, schools

In 1994 to 1995 achievement tests in Mathematics and Science were administered to scientifically designed random samples of students in classrooms around the world. Concurrent with these tests, students, their teachers and their school principals were asked to respond to questionnaires about their backgrounds, attitudes, parental expectations, extracurricula activities and practices in the teaching and learning of Mathematics and Science. To quote the TIMSS publicity brochure (1996 (g): no page number):

> In total, TIMSS collected information from students, teachers, and school principals on approximately one thousand five hundred contextual variables related to the teaching and learning of Mathematics and Science.

Whilst ranking was of importance to some of the participating countries it should not be overlooked that TIMSS was also intended to identify common features and differences in the education systems that were examined.

4.1.4.2.(b) Language

In order to address language and culture differences, the TIMSS Study Centre made provision for translation and control processes.
The language check and control processes involved:

- the substitution of Standard English spelling for American spelling;
- the replacement of non-South African elements. For example, a snowshoe rabbit became a spring hare; dollars were changed to rands;
- the translation of these South African English papers into Afrikaans;
- the English and Afrikaans versions of the papers being assessed for suitability by a panel of local teachers; and

- the final approval by language experts in Boston.

4.1.4.2.(c) Curriculum analysis: its complexity and significance

By far the most complex aspect of the TIMSS programme was that of curriculum analysis. The process of comparing curricula on an international basis is fraught with difficulty since there are no methods of achieving direct comparisons. There are additional difficulties in comparing curricula through an examination of performances using selected test items. For example, underlining the inherent deficiencies of curriculum-based test instruments, Hoy and Gregg (1994: 403) state:

> ... criterion-referenced measures and inventories can provide invaluable information during development of an individualized education program [sic] with specific instructional objectives. However, the special education teacher must be aware that these measures may not match the mathematics [or science] curriculum used in a particular school. Therefore, it is the responsibility of the special education teacher to examine the mathematics [and science] curriculum to ensure that the student has had the opportunity to learn the objectives identified as weaknesses by criterion-referenced measures.

Nonetheless, as Hoy and Gregg (1994: 402) also acknowledge:

> Criterion-referenced tools and inventories [do] assist in identifying which instructional objectives the student has mastered and which need further work.

Thus, notwithstanding implied and observed national and international variables, TIMSS adopted the curriculum-based approach to identify similarities and differences.

4.2 THE CONCEPTUAL FRAMEWORK OF TIMSS

4.2.1 THE CURRICULUM APPROACH

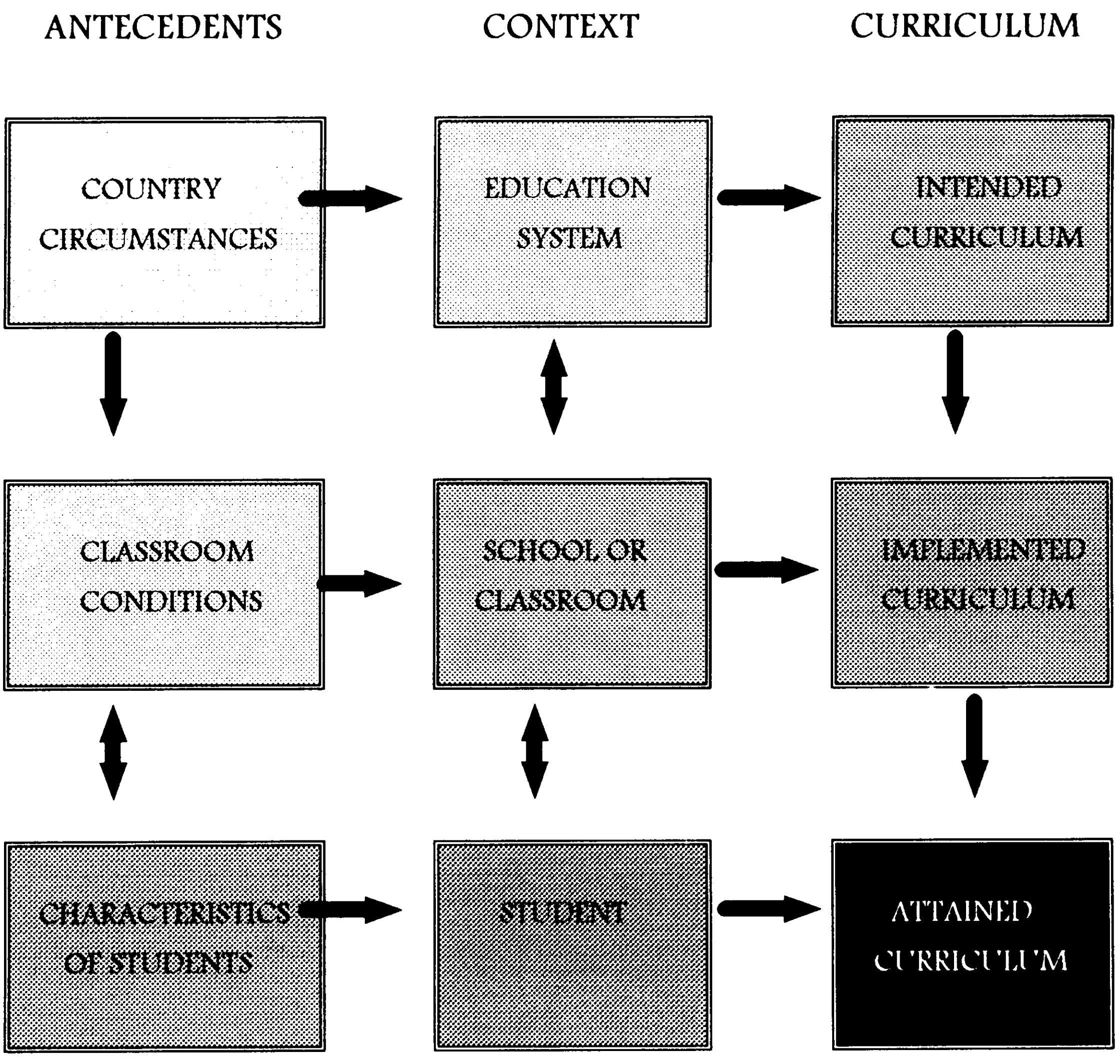
In order to address the curricula differences referred to above, the TIMSS tests were constructed on the basis of Curriculum Frameworks. These were devised through a careful analysis of the textbooks and other 'official' material used in the teaching of Mathematics and Science in all participating countries. The strategy of TIMSS is to examine Mathematics and Science education through a tripartite approach to the curriculum: the Intended Curriculum, the Implemented Curriculum and the Attained Curriculum as shown in Table 4.1 below.

- The **Intended Curriculum** is the Mathematics and Science content as defined at the national or educational system level.

- The **Implemented Curriculum** is the Mathematics and Science Curriculum as interpreted by teachers and made available to students.

- The **Attained Curriculum** is the Mathematics and Science content which students have learned.

Table 4.1 The context and components of the school curriculum (Robitaille & Garden, 1996: 35)

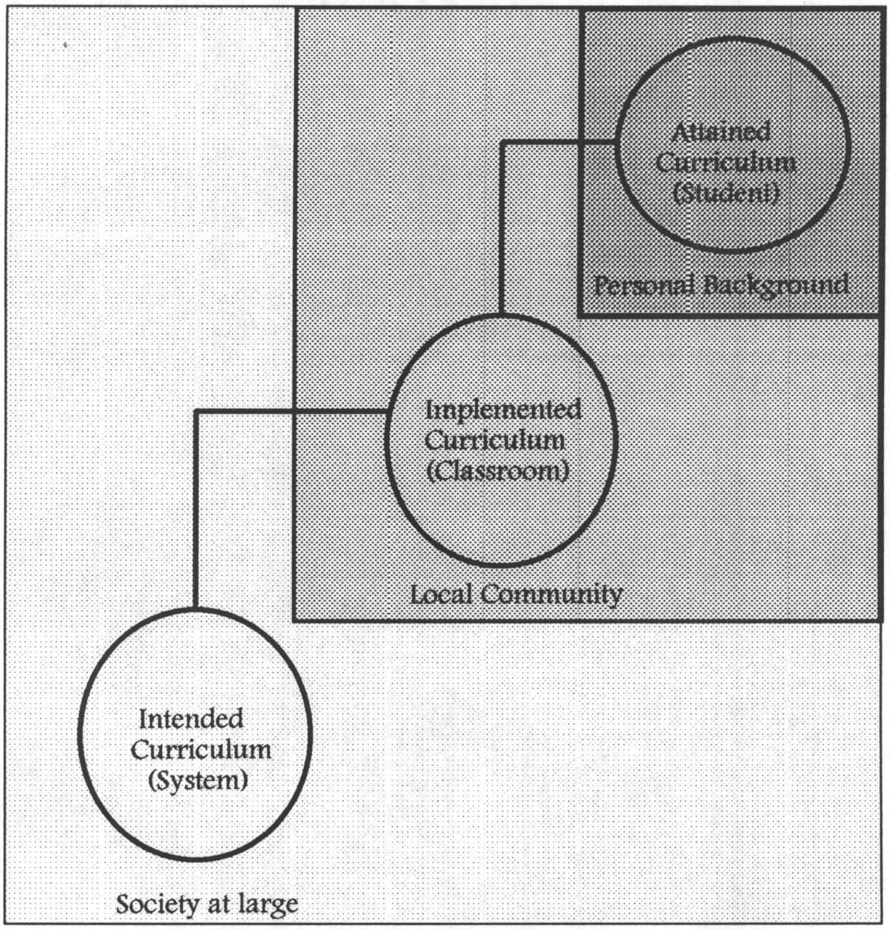


4.2.1.1 Explanation of the aspects of the Curriculum Framework

The three dimensions of the TIMSS Curriculum Framework illustrated in Table 4.1 above are further subdivided into the Content Aspect, the Performance Aspect and the Perspectives Aspect. These elements are discussed more fully later in this chapter (see 4.3.1).

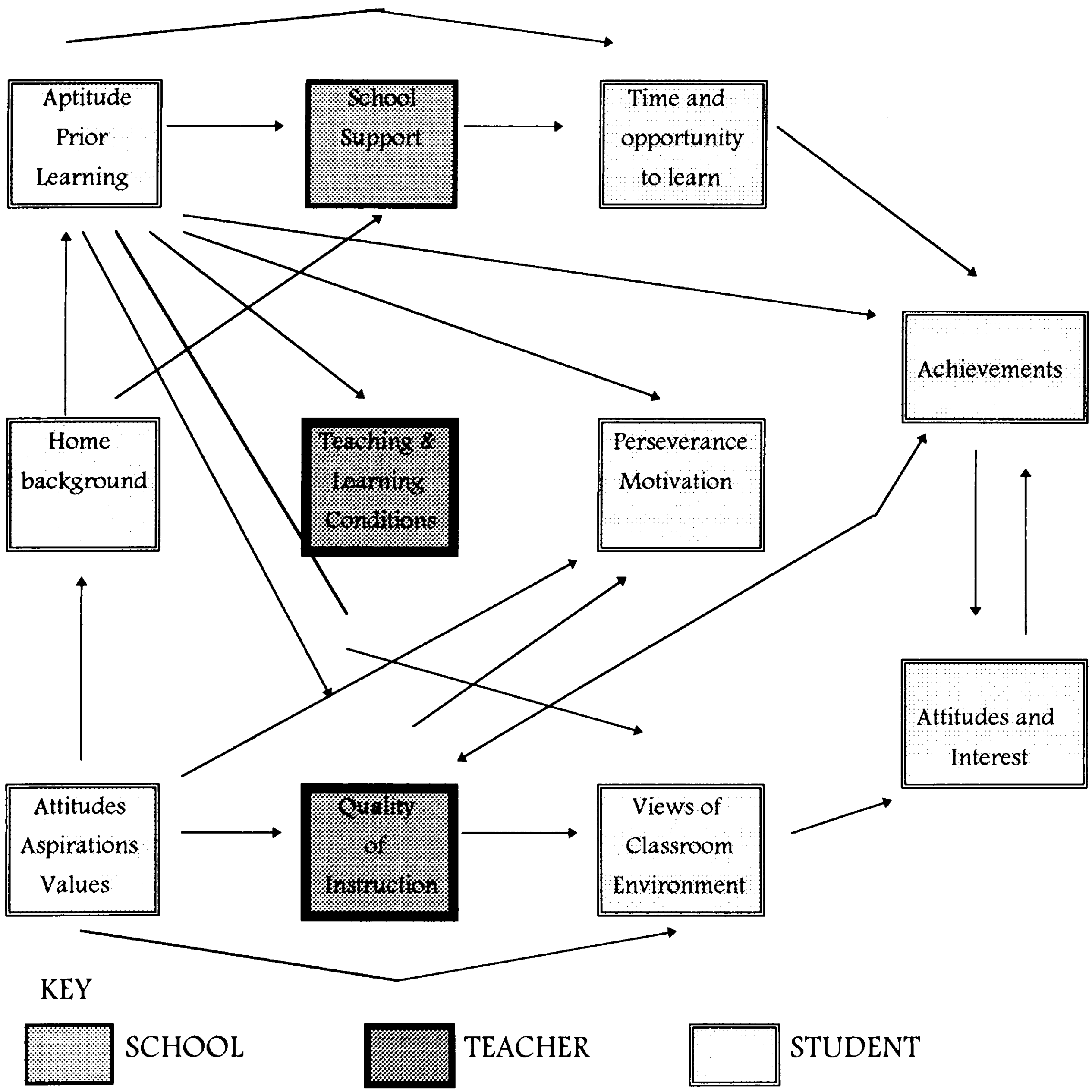
The derivative and enclosing relationships between the three aspects of curriculum are shown in the VENN-type diagram below.

Figure 4.1 The interrelations of the various aspects of the curriculum



If the interacting components of Figure 4.1, above, are abstracted, then the multiple impact of the Country Circumstances, School and Classroom on the Attained Curriculum can be clearly seen. The vector influences of the education environment on the educational outcomes are demonstrated below.

Figure 4.2 School performance and the factors that influence it (Robitaille & Garden, 1996: 36)



4.2.1.2 Application of the Curriculum Framework

National characteristics, such as economic and time investment, political and social policies and other macro-influences on education, as discussed in Chapter 3 of this thesis, ultimately determine the nature of the Intended Curriculum. In the same way, national policies will determine the classroom environment in which teaching takes place. These influences create the Implemented Curriculum, which may, or may not, represent a considerable modification of the Intended Curriculum, in terms of what is taught, with what emphases and with what outcomes.

School and classroom conditions, in turn, impact on the student. These factors, in combination with the students' home and social backgrounds and their own personal attitudes, all serve to contribute to or detract from scholastic achievement. In more complex terms the social, administrative and educational vectors influencing educational outcomes can be represented as shown in Figure 4.2 above.

Domestic circumstances and the South African Education System have already been described in the previous chapter. School/Classroom conditions and the Implemented Curriculum are considered in some detail in Chapter 6 together with a profile of the South African students who participated in TIMSS. The Attained Curriculum, as reflected in the TIMSS achievement tests, is examined in Chapter 5.

4.3 CURRICULUM CODING AND COMPARISONS (TIMSS, 1993 (d.))

As already inferred, testing and evaluation systems vary considerably from one country to another, and while they may be an indication of the sort of curriculum envisaged, they can give little indication of a 'universal or international degree of difficulty'. Useful and informative comparisons can be made, however, if the Intended Curriculum is segmented into its component parts and examined in some depth. This important aspect of the TIMSS study is, as yet, not fully appreciated.

If a view of the curriculum dealing with aspects of concepts, processes and attitudes towards selected subjects such as Mathematics and Science is adopted, it becomes possible for any section of the 'official' curriculum to be coded. This enables comparisons between the Mathematics and Science curricula frameworks to be made. In South Africa, the Curriculum Analysis and coding of syllabi and Teachers' Guides was carried out, after suitable training, by staff of the then Education Departments who were seconded to the TIMSS project for periods varying from ten to twelve working days depending on the subject and the quantity of material to be analysed.

These coding aspects of comparisons between curricula will be discussed more fully in a consideration of the interactions of the determinants of the curriculum in a later paragraph. It should be realised though, that curriculum analysis gives little indication of the intensity with which topics are taught, or the depth of content taught; and no indication can be given of the depth to which a topic is examined or the breadth of knowledge expected from the students.

4.3.1 THE THREE DIMENSIONS OF THE TIMSS CURRICULUM FRAMEWORK

As already noted and as illustrated in Tables 4.2 and 4.3 below, there are three dimensions or aspects to the TIMSS Curriculum Framework. The Content Aspect represents the subject content of school Mathematics and Science. The Performance Aspect describes, in a non-hierarchical way, the many kinds of performances or behaviours the content might elicit from students. The Perspectives Aspect focuses on the development of students' attitudes, interests, and motivations in Mathematics and Science.

Table 4.2 The three aspects and major categories of the Mathematics curriculum framework (TIMSS Fact Sheet, 1996 (a): no page number)

1. CONTENT ASPECTS

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

2. PERFORMANCE ASPECTS

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

3. PERSPECTIVE ASPECTS

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

Table 4.3 The three aspects and major categories of the Science curriculum framework (TIMSS Fact Sheet, 1996 (a): no page number)

1. CONTENT ASPECTS

- Earth Sciences
- Life Sciences
- Physical Sciences
- Science, Technology and Mathematics
- History of Science and Technology
- Environmental issues
- Nature of Science
- Science and other Disciplines

2. PERFORMANCE ASPECTS

- Understanding
- Theorizing, analysing, solving problems
- Using tools, routine procedures
- Investigating the natural world
- Communicating

3. PERSPECTIVES ASPECTS

- Attitudes
- Careers
- Participation
- Increasing interest
- Safety
- Habits of mind

4.3.1.1 The Content Aspect

The content-based approach to any school focus or subject

> ... offers an important framework from which to interpret and use achievement test scores,

as Walshe and Betz (1985: 202) observe. The use of such tests for designing further instructional models is probably the primary example of this utility. In clarification, a simple example makes the point:

Knowledge that a nation's competency in Mathematics is high in Algebra but lower in Geometry and Trigonometry would probably be of more use in planning curriculum renewal than would knowledge that the national score in a Mathematics achievement test was at the 50th percentile.

4.3.1.2 The Performance Aspect

This component of the analysis covers the skills that are expected from the student. Performance analysis is a breakdown of the instructional components of the educational material into the main logical sub-divisions of the field. For example, school level Mathematics is divided into ten major areas. This grouping of ten expectations appears to be a satisfactory division whilst escaping the inevitable 'atomization' of the subject that could well be inevitable if a more detailed subdivision were attempted. It is from an examination of these aspects of the curriculum that the level of mathematical or scientific expectations in the various fields can be judged.

4.3.1.3 The Perspective Aspect

This aspect of curriculum analysis is intended to depict curricula goals and will make it possible to describe learning outcomes. That is, what the curriculum content does to promote the subject and its 'career' applications and relevance. This Perspectives Aspect also gives an indication of how the 'culture' of Mathematics or Science is intended to be transmitted.

Gronlund & Linn's (1990: 24) view that

> ... effective evaluation depends as much on a clear description of *what* is to be evaluated as on a determination of *how* to evaluate.

provides some justification for the complexity of TIMSS. The *what* is complicated by the large number of differing national systems to be evaluated and the *how* inevitably becomes a compromise between the ideal and the pragmatic.

4.3.2 ANALYSIS OF THE INTENDED CURRICULUM

The Intended Curriculum (Schmidt, 1993: no page number) is regarded as:

> ... any "official" document, published or distributed, teacher's guides or schemes of work and the best selling officially recognized textbooks.

Analysis of the Intended Curriculum is achieved by means of a detailed analysis of textbooks, official curricula and teachers' guides. In the South African case, some thirty textbooks and other official publications were closely analysed, coded and the collated data was then transmitted to the Curriculum Study Centre at the Michigan State University for merging with the international data base. The intention is that a world data base of analysed materials will be available for call by any researcher in the world.

4.3.2.1 Coding of textbooks and other curriculum related materials

4.3.2.1.(a) The rationale

As Table 4.4 below indicates, coding of the Intended Curriculum was undertaken to determine the three interrelated facets of the Curriculum Framework, that is, Content, Performance and Perspectives (see also Tables 4.2 and 4.3 above).

Table 4.4 Information considered in Curriculum coding

To study	The official (Intended Curriculum)
To determine	What topics are taught. When topics are taught. What student performances are expected. What attitudes are intended.

4.3.2.1.(b) Demarcating instructional blocks in textbooks

Each textbook is dissected into a series of continuous 'blocks' of instructional material. Each item or block of material or information unit in these curriculum resources was coded with a three or four figure code (see Appendix 2) with regard to its:

- content (1)
- performance expectations (2), and
- perspectives (3)

4.3.2.1.(c) Content

This is the learning matter and content requirements of the curriculum. Code numbers for content all begin with the code number 1.

4.3.2.1.(d) Performance

These expectations are regarded as those skills and dexterities which students are stated as being expected to master. Examples given in the TIMSS curriculum analysis guide for Science include:

- Carrying out a titration
- Culturing a bacterial growth

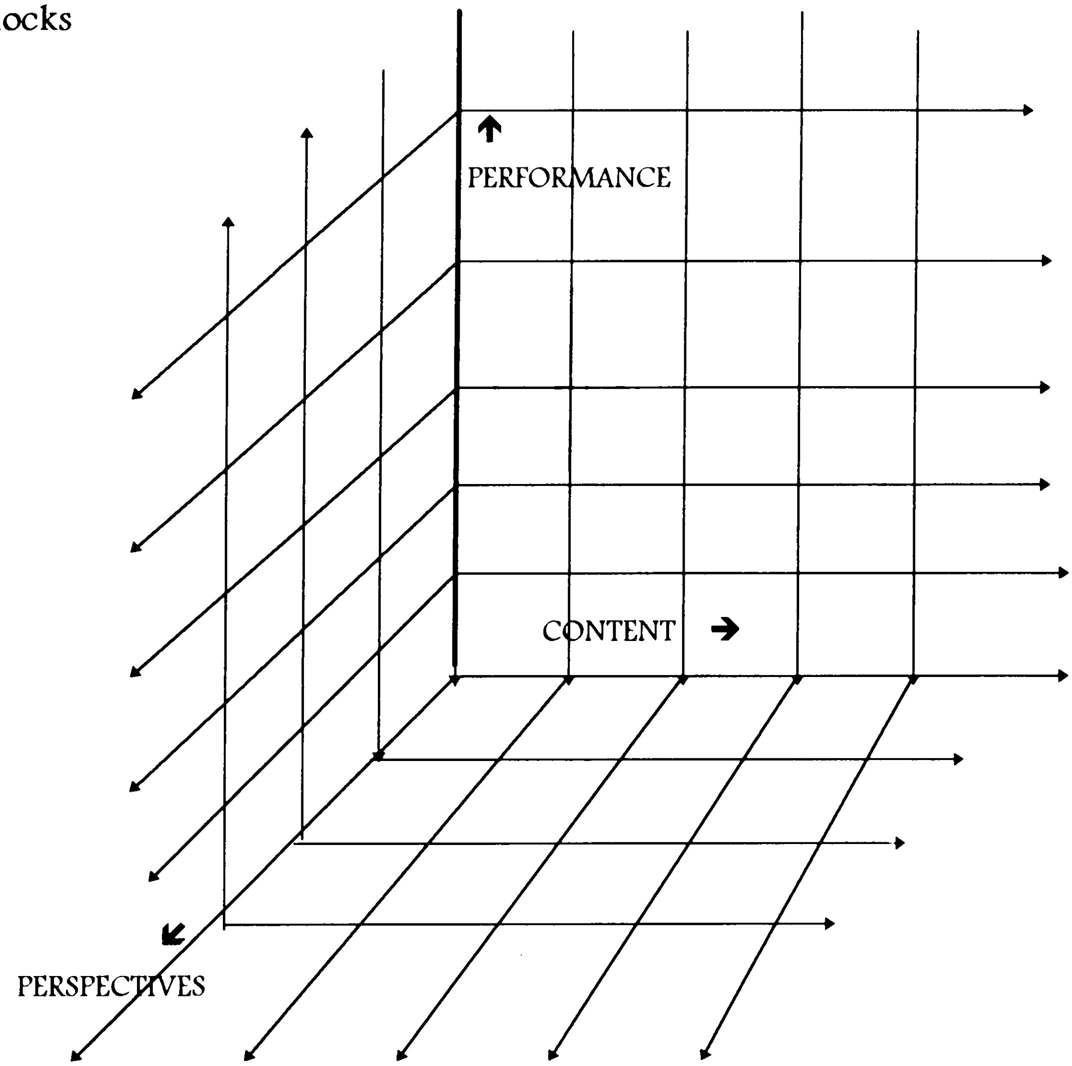
Other performance aspects that are coded include laboratory safety. Performance codes begin with a 2.

4.3.2.1.(e) Perspectives

A philosophy of science is looked for within the curriculum. Redress to gender imbalances, access of underrepresented groups in Mathematics and Science classes and career guidance content are also looked for and grouped under Perspectives. Perspectives codes begin with a number 3. The full coding frameworks for both Mathematics and Science are attached as Appendix 2.

Completion of the coding process enables each small unit of the curriculum to be positioned in respect of three co-ordinates as shown in Figure 4.3 below. A sample analysis form is attached as Appendix 3 as referred to in 4.3.2.1.(b).

Figure 4.3 A three-dimensional framework for coded instructional blocks



In addition to this document analysis, an In-depth Topic Trace Map is compiled for selected themes through the whole range of schooling from Grade 1 to Grade 12.

4.3.2.2 In-depth topic trace mapping

In-depth Topic Trace Mapping [ITTM] is intended to follow the development of identified critical concepts through the entire period of a student's education. ITTM identifies when certain topics are taught in the school curriculum. Schools deal with these topics in different grades. ITTM also serves to inform the researcher of the type of exposure students are intended to experience in certain Mathematics and Science topics throughout their school careers. In addition, ITTM provides the order in which each topic is presented, as well as the degree and depth of emphasis with which they are treated at different grade levels.

Examples of the themes, as provided by the TIMSS Curriculum Analysis Guide (TIMSS, 1993 (d)), followed by the TIMSS programmes include:

- Fractions and Proportionality
- Linear equations
- Human Biology
- Energy

Table 4.5 The similarities and differences between Document Analysis and In-depth Topic Trace Mapping (Schmidt, 1993 (d)):

	In-depth topic trace mapping	Document analysis
Type of material analysed	Curriculum guidelines Textbooks and Textbook series	Curriculum guidelines Textbooks
Grades	All grades	TIMSS population grades only
Subject matter topics of interest	4 selected topics from the TIMSS frameworks When topics are introduced	All topics from TIMSS frameworks Which topics are intended
Data provided about topics	When topics are introduced When topics are completed What instruction is intended throughout all the school years.	What kinds of student performances are expected What emphasis is given to topics and student performances

4.3.3 ANALYSIS OF TEXTBOOK STRUCTURE AND OFFICIAL CURRICULUM GUIDES

This process is essentially one of dividing a textbook up into a number of units or blocks which are defined as the smallest instructional components in the text. Each instructional unit is also allocated a descriptive code as to its general content thus:

Table 4.6 Block classification (TIMSS, 1993 (d): Coding form number DA-3)

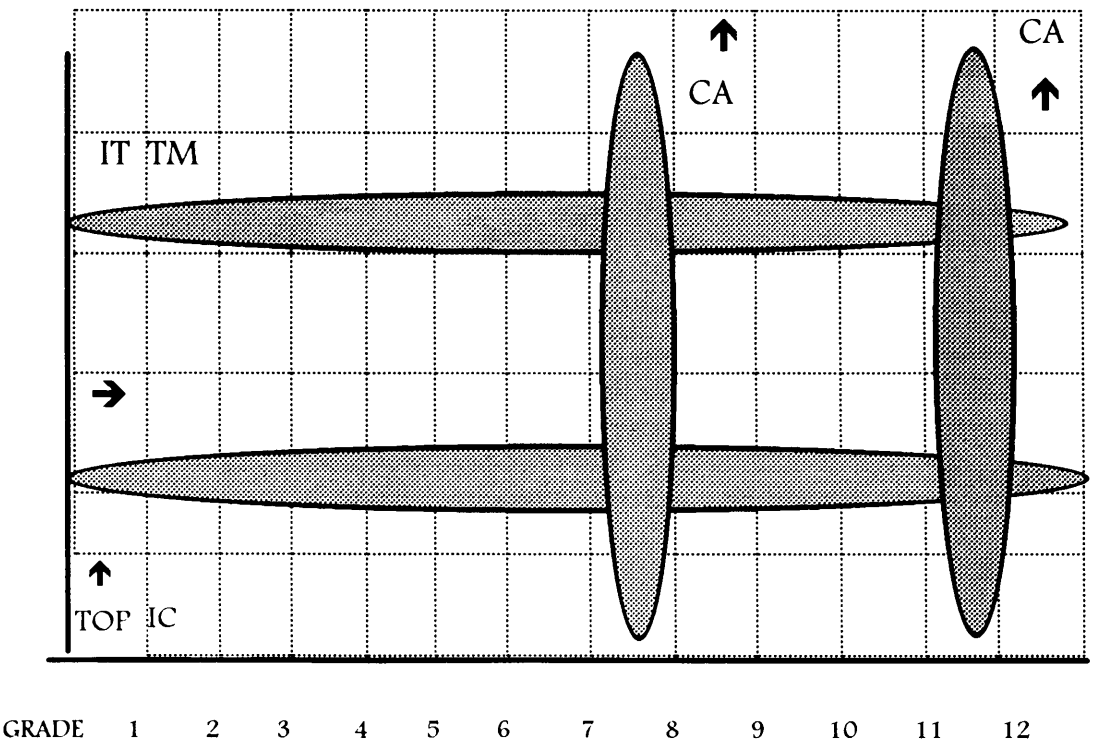
CODE	TYPE OF BLOCK	
1.	NARRATIVE BLOCK	All blocks of text relating directly to the topic content.
2.	RELATED NARRATIVE BLOCK	Blocks containing supporting content to the topic.
3.	UNRELATED INSTRUCTIONAL NARRATIVE BLOCK	Blocks containing background or enrichment information.
4.	RELATED GRAPHIC BLOCK	Is a graphic that relates directly to an instructional block.
5.	UNRELATED GRAPHIC BLOCK	Is a graphic containing related or back-ground information. e.g. Historical information.
6.	EXERCISE/QUESTION SET	Are sub-sets of related questions or exercises.
7.	UNRELATED EXERCISE/ QUESTION SET	Exercises or questions not related to the narrative block preceding the exercise block. e.g. revision exercises or enrichment questions.
8.	ACTIVITY BLOCK	Activities or experiments or investigations
9.	WORKED EXAMPLES	Examples demonstrating an algorithm or method worked out and demonstrated.
10.	OTHER BLOCKS	Any identified block that does not fit naturally into the nine defined blocks.

All supporting curriculum guides undergo a similar block coding and description process as indicated in Table 4.7 below.

Table 4.7 Allocated codes for official guides (TIMSS, 1993 (d))

CODE	TYPE OF CONTENT
0.	Introduction
1.	Policy Units
2.	Objective Units
3.	Content Units
4.	Pedagogy Units
5.	Other Units

Figure 4.4 The relationship between In-depth Topic Trace Maps [ITTM] (between years) and Curriculum Analysis [CA] (within a year) (TIMSS, 1993 (d))



The Figure above shows the interrelationship between subject content within a particular year and continuously between years. This analysis allows examination of the treatment of identified central themes.

4.3.3.1 The data that can be extracted from coded curricula

Any single identified topic can be recalled from a curriculum analysis data base and its frequency and occurrence can be compared with occurrences in the curriculum analysis of other countries. Thus, for example, if it is desired to examine the introduction of fractions, a search process for the codes: 1.1.2.1 (Common fractions [meaning and representation of common fractions and mixed numbers]) can be carried out on the national data-bases required. The occurrences of the identified codes will enable detailed comparisons to be made. On the same basis, frequency of recurrence of the selected code will give an indication of the intensity with which this topic is taught in different countries.

4.3.3.2 Comparisons and internal structure of textbooks

The three tables below (4.8, 4.9 and 4.10) show the internal Instructional Block sequence for two text-books, one South African and one Australian for the pages that deal with the same topics. This extract of one hundred and thirty instructional blocks in both cases covers about thirty-five pages (Australian data sheet supplied by W. Schmidt, 1994).

Table 4.8 An analysis of the block sequence of a South African Standard 10 Mathematics textbook.

BLOCK NUMBER	1	2	3	4	5	6	7	8	9	10
1	1									
2	1									
3			3							
4	1									
5	1									
6						6				
7	1									
8				4						
9				4						
10				4						
11				4						
12	1									
13		2								
14	1									
15									9	
16						6				
17						6				
18						6				
19						6				
20						6				
21	1									
22	1									
23									9	
24						6				
25						6				
26						6				
27	1									
28	1									
29	1									
30		2								
31			3							
32				4						
33					5					
34	1									
35									9	
36						6				
37						6				
38									9	
39						6				
40						6				
41	1									
42				4						
43								8		
44	1									
45				4						
46								8		
47	1									
48	1									
49	1									
50									9	
51						6				
52						6				
53									9	
54						6				
55									9	
56						6				
57									9	
58						6				
59									9	
60						6				
61						6				
62						6				

BLOCK TYPE	1	2	3	4	5	6	7	8	9	10
63		2								
64		2								
65		2								
66	1									
67									9	
68									9	
69									9	
70						6				
71	1									
72									9	
73						6				
74									9	
75						6				
76						6				
77						6				
78									9	
79						6				
80	1									
81									9	
82									9	
83										
84		2								
85									9	
86	1									
87						6				
88						6				
89						6				
90						6				
91						6				
92						6				
93						6				
94						6				
95									9	
96		2								
97						6				
98	1									
99	1									
100				4						
101	1									
102						6				
103								8		
104								6		
105								6		
106								6		
107	1									
108				4						
109									9	
110									9	
111									9	
112						6				
113						6				
114						6				
115						6				
116						6				
117						6				
118						6				
119						6				
120						6				
121	1									
122									9	
123				4						
124	1									
125						6				
126									9	
127						6				
128				4						
129						6				
130									9	

Table 4.9 An analysis of the block sequence of an equivalent overseas Mathematics textbook. (Schmidt 1993)

BLOCK NUMBER	1	2	3	4	5	6	7	8	9	10
1	1									
2	1									
3		2								
4		2								
5				4						
6				4						
7									9	
8									9	
9						6				
10						6				
11						6				
12						6				
13	1									
14	1									
15									9	
16									9	
17						6				
18						6				
19			3							
20			3							
21					5					
22			3							
23			3							
24	1									
25	1									
26		2								
27				4						
28									9	
29									9	
30						6				
31						6				
32						6				
33									9	
34									9	
35								8		
36								8		
37						6				
38						6				
39									9	
40									9	
41									9	
42										
43										
44										
45										
46								8		
47	1									
48	1									
49	1									
50									9	
51						6				
52						6				
53									9	
54						6				
55									9	
56						6				
57									9	
58						6				
59									9	
60						6				
61						6				
62						6				

BLOCK TYPE	1	2	3	4	5	6	7	8	9	10
63	1									
64	1									
65	1									
66		2								
67		2								
68									9	
69						6				
70						6				
71							8			
72	1									
73		2								
74		2								
75			3							
76			3							
77				4						
78									9	
79									9	
80						6				
81				4		6				
82				4						
83						6				
84	1									
85		2								
86		2								
87			3							
88		2								
89									9	
90						6				
91						6				
92						6				
93									9	
94									9	
95						6				
96				4						
97				4						
98						6				
99				4						
100			3							
101	1									
102	1									
103		2								
104		2								
105									9	
106									9	
107						6				
108						6				
109				4						
110						6				
111		2								
112		2								
113			3							
114									9	
115			3							
116						6				
117						6				
118								8		
119								8		
120								8		
121	1									
123	1									
124		2								
125		2								
126			3							
127				4						
128				4						
129	1									
130	1									

Table 4.10 Percentages of selected block types

Block Code Number	Block Type	SOUTH AFRICAN TEXT (percentages)	AUSTRALIAN TEXT (percentages)
6.	Exercise/question blocks	40	26
9.	Worked Example blocks	19	19
1.	Narrative blocks	22	17
2.	Related narrative blocks	5	12
3.	Unrelated instructional block	2	9
4.	Related Graphic block	8	8
8.	Activity blocks	2	5

4.3.3.2.(a) Findings

Examination of the two analytical tables above suggests that:

- The South African book contains considerably more exercise blocks, which leaves the impression that this text is more of an exercise book than an instructional text (Block type 6).
- The South African text suggests that Mathematics is not activity based (Block type 8).
- There appears to be significantly more instructional material and less supportive text in the South African book (Block types 1 and 2).
- The South African text provides considerably less support and enrichment material than the Australian text (Block type 3).
- The Australian text reveals a sequence or flow of development of the theme which appears to be almost absent in the South African book. The sequence observable is that of Instructional material (Block type 1) followed by supportive material (Block type 2) often followed by enrichment material (Block type 3), both linked to graphics (Block type 4) .

- Worked examples in the Australian textbook are regularly followed by examples/questions in a more integrated sequence with interspersed development of the theme through instructional passages.

4.3.3.2.(b) Deductions

- The Intended Curriculum helps to explain students' accomplishments in tests, in particular, in the TIMSS tests and the opportunities they had in Mathematics and Science instruction to achieve them.
- The ability to organize ideas in written language and arrange them to create an organizational plan involves many linguistic and cognitive skills (Scardamalia, Bereiter & Goelman, 1982: 173).
- The teacher investigating the students' ability to learn must take cognizance not only of such factors and the age of the student, his or her logical reasoning ability, cognitive skills and experience but also of the effectiveness of the educational tool, that is, the textbook.
- The students' exposure to, and grasp of, a topic may be enhanced or inhibited by the design and the extent to which the textbook is 'user-friendly', that is, by the ways in which such topics are presented and reinforced (cf. Skinner and Piaget in 2.1.3.5 and 2.1.4.4 respectively).

4.4 THE TIMSS TARGET POPULATIONS

Although the intention of TIMSS was to investigate the achievement of school students at three age levels, which are defined below, only two of these levels were practicable in the local South African context. The three target groups defined by age level are described in Chapter 1 of this thesis and are elaborated on below.

4.4.1 POPULATION 1 [Pop1]

This is defined as the two adjacent grades of school students containing a majority of nine year olds. South Africa did not enter this aspect of the TIMSS study on the grounds of cost and other difficulties of operating the sessions, such as conducting tests in the eleven official languages for the Standard 2 students (who receive mother-tongue instruction up to this stage). It was also regarded as being patently unfair to test the majority of Standard 3 students in English (the Standard 3 medium of instruction) in which some pupils would only have had seven or eight months of instruction.

4.4.2 POPULATION 2 [Pop2]

This is defined as those two adjacent grades in which the majority of thirteen year old students are attending school. For South Africa this is Standards 5 [Grade 7] and Standard 6 [Grade 8]. It transpired that this population group became the most effective one for South Africa and so is the focus of this study. In some ways this Grade distribution is fortuitous in that TIMSS has gathered data on the performance of primary school students (Standard 5), middle school students (in the North West Province and in the Eastern Province) and in secondary schools (Standard 6). This permits some interesting observations to be made on the efficacy of middle schools and it also enables an investigation to be made into the effects on learning of transfer from primary to secondary school. It is worth noting that in contrast to Sweden, where it is claimed that 98.5 per cent of their thirteen year old students are in a single Grade, only 48.6 per cent of South African thirteen year old students fall into both these grades together. No other pair of adjacent grades contain a greater percentage of thirteen year olds. This low percentage of thirteen year olds in the selected grades was unique in the TIMSS study and this will inevitable impact on statistically processed test scores in terms of an 'old' population studied.

4.4.3 POPULATION 3 [Pop3]

This study group was originally defined as those students who were in their final year of schooling. This apparently simple definition becomes a very complex matter to resolve both locally and abroad because 'the last year of schooling' becomes very difficult to define in countries such as Germany, where older school students move into sandwich courses distributed between school and vocational training centres, while in some third world countries the last year of schooling may be anything from Grade 1 to post Grade 12. If the South African case is considered, it will be seen that it is virtually impossible to stipulate that any particular year is the final year. This is because substantial numbers of students drop out either during or at the end of each year of schooling. Thus it can have been argued that approximately 20 per cent of Standard 2 students are in fact 'in their final year of schooling' and should therefore be included in the Pop3 sample. However, compromises were therefore sought and reached at National Research Co-ordinators' [NRC] meetings and ultimately only Standard 10 [Grade 12] students were tested in this group. After several reviews and modifications at these meetings, achievement tests were offered in Population 3 as Generalist papers (2) and Specialist papers (3). These latter papers were directed at students in 'their final year of schooling' and who were being prepared for tertiary education. These papers included: Mathematics for Specialists, Physics for Specialists, and a combined Mathematics and Physics Specialist paper. South Africa, after considerable discussion, and reference to representatives of all the Provincial Education Departments, decided to offer only the Generalist aspect of Pop3 for evaluation which is not reported on in this study.

4.5 THE SAMPLING PROCESS

Of necessity the sampling design for TIMSS is complex so as to cater for the large number of national education characteristics and to ensure a high quality of sample profiles from each of the participating nations. Sampling for TIMSS is a two-tiered stratified sample cluster. There are three reasons for this stratification:

- to produce reliable estimates of sub-national domains;
- to improving sampling efficiency and thereby reduce the national sample size to a valid minimum. Ideally this was to be one hundred and fifty schools per country.
- to ensure all parts of the population are appropriately represented in the national sample.

4.5.1 DIRECTIVES FOR ESTABLISHING THE SAMPLING FRAMEWORK

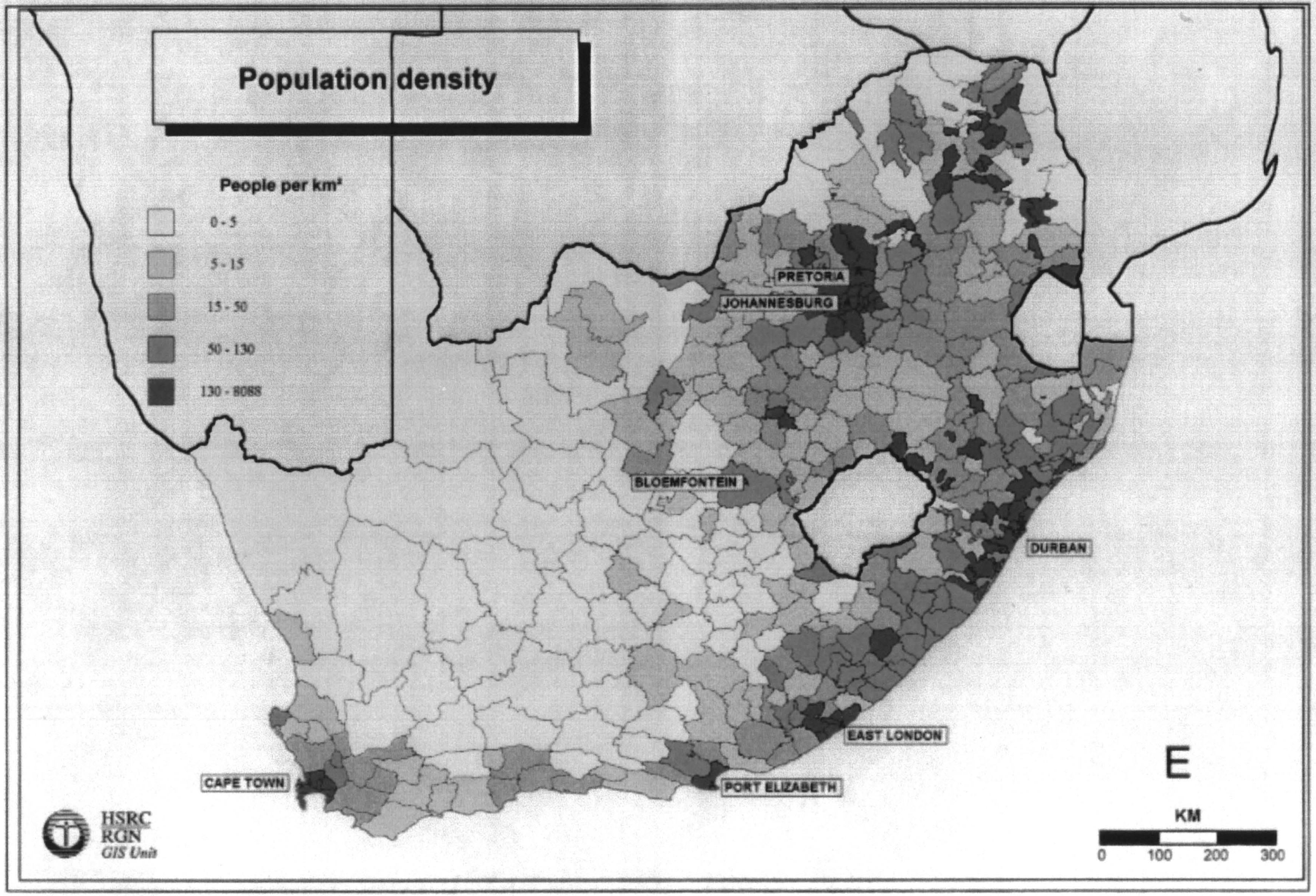
National Research Co-ordinators were required to

- develop a national sampling frame or list of eligible schools;
- define and obtain recognition for required exclusions from the Sample refereeing panel;
- to select the schools in an approved manner from the approved sampling framework;
- to select those classes to be tested from within the school classes;
- to collect the relevant data such as class lists, ages and names; and
- to complete the TIMSS administration forms with the required data on schools and classes.

The original conditions placed on South Africa for participation in TIMSS included an undertaking not to attempt any racial grouping in the sample or in any final analysis. Thus, with the exception of a very few schools for the educationally handicapped and agreed exclusions (discussed later) the sample was drawn from the whole of the national population in Standards 5 and 6.

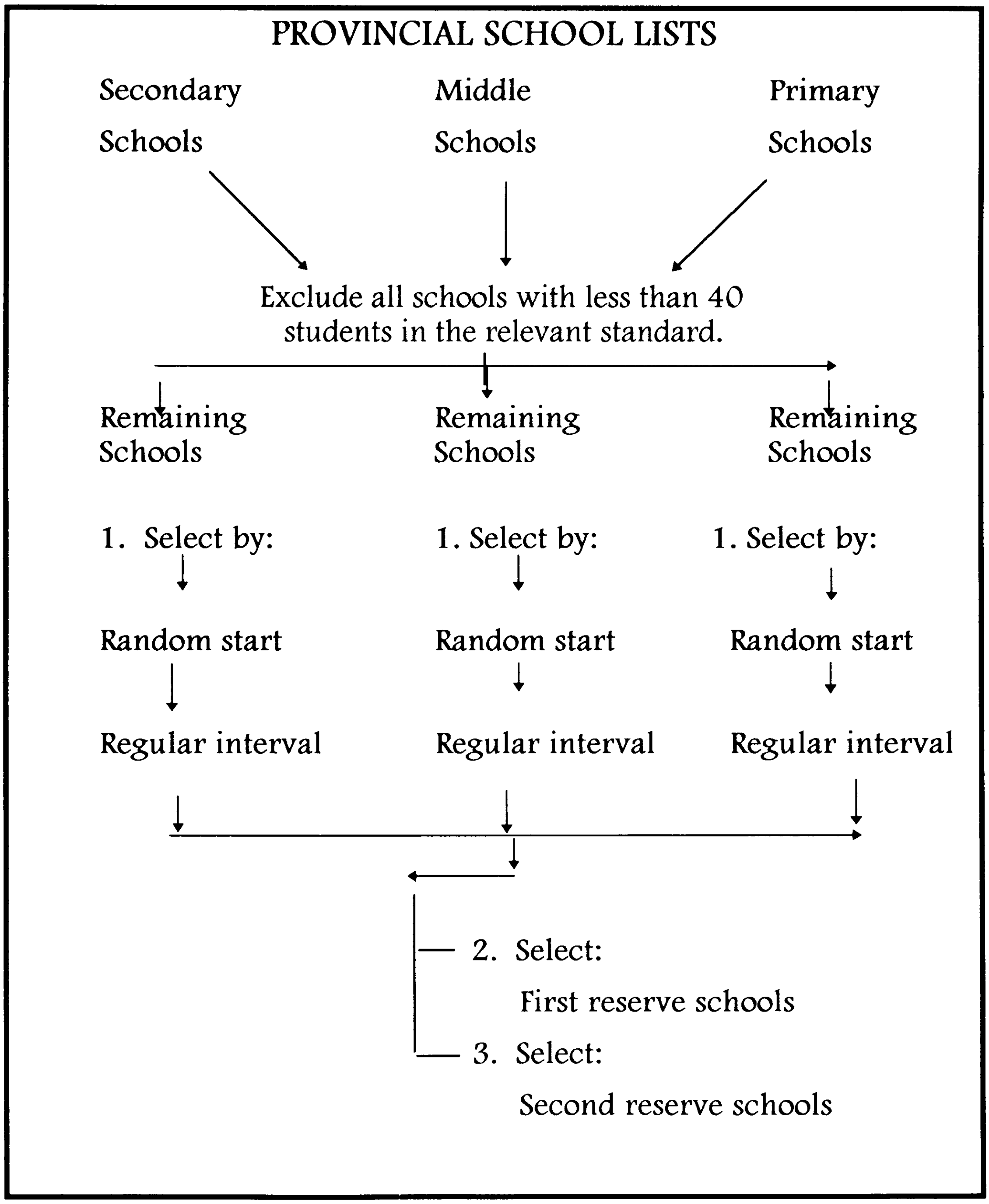
4.5.1.1 Procedure

- South Africa was subdivided into nine political provincial regions according to best estimates available at the time of drawing up the sampling framework, that is at the end of 1993 when the new provinces had not yet been officially designated (see population distribution map over the page).
- The South African sample that was negotiated originally consisted of three hundred schools owing to the complexity of the schooling system structure and the division of primary school and secondary school between Standards 5 and 6. This was later reduced to two hundred and seventy-seven schools in the light of the existence of middle schools with both Standards 5 and 6 in the same school and where both classes could be tested.
- The provincial lists were then examined for schools that were to be excluded from the empirical study on the grounds of enrolment in the Standards being tested (see Figure 4.5 and 4.6.1 below).
- The remaining schools were then listed in ascending order of enrolment numbers using the best data available. This information was obtained from the relevant Departments of Education and from the HSRC Data Base of Schools. It was from these listings that the Statistics Centre confirmed the number of schools required for the South African sample.
- Individual schools were then selected from each of the provincial lists by starting from a randomly generated


Population density
People per km²
0 - 5
5 - 15
15 - 50
50 - 130
130 - 8088
PRETORIA
JOHANNESBURG
BLOEMFONTEIN
DURBAN
EAST LONDON
PORT ELIZABETH
CAPE TOWN
E
KM
0
100
200
300
HSRC
RGN
GIS Unit

number to position the first school in each provincial sample. The selection continued on each list by selecting schools at appropriate ~~intervals~~ until the full provincial quota had been drawn. First and second reserve schools were identified for each sample school in the same way.

Figure 4.5 The South African sampling process



- A group of forty-seven test administrators from MARKDATA, the HSRC Survey Agency were trained according the TIMSS Test Administrators manual and the selected schools were visited by these test administrators/co-ordinators. This obviated the need to train and make use of test co-ordinators as well as test administrators from the schools. Testing in this way had the effect of ensuring uniformity in the application of the testing procedures.

Table 4.11 The profile of the final sample

Province	Primary Schools	Middle Schools	Secondary Schools	TOTAL	%
Eastern Cape	13	13	19	45	16.2
Free State	6	3	11	20	7.2
Gauteng	19	2	18	39	14.0
KwaZulu-Natal	33	1	32	66	23.8
Mpumalanga	11	-	13	24	8.6
Northern Cape	2	-	2	4	1.5
Northern Province	24	2	26	42	15.1
North West Province	-	14	-	14	5.0
Western Cape	11	1	11	23	8.3
TOTALS	119	36	132	277	

(It is interesting to compare the population distribution map 4.1 above with the distribution of the realised sample of schools [see map 4.3 later in this chapter].)

4.6 CONSTRAINTS ON THE SOUTH AFRICAN SAMPLING PROCESS

4.6.1 EXCLUSIONS

It had been decided by the South African TIMSS office in consultation with National Education Department staff that all schools with less than forty students in the TIMSS 'Population 2' Grades (Grades 7 and 8 which, as already mentioned, are the South African Standards 5 and 6) were to be excluded. The principal reason for this exclusion was that the majority of the traditional 'farm schools' were, for practical purposes, geographically inaccessible. Moreover, the management of many of these small rural schools was, at that time, somewhat uncertain.

4.6.1.1 Pseudo schools

South Africa gave no consideration to the construction of pseudo-schools or agglomeration of two or more smaller schools into a single larger 'statistical' school for sampling purposes. This technique was devised by the International Sampling Review Committee to allow for the incorporation of smaller schools into national samples.

4.6.2 TESTING WITHIN SCHOOLS

TIMSS - South Africa was restricted by Heads of Departments of Education (HEDCOM, 17 January 1995) to testing intact classes to ensure minimum disruption to normal schooling in the selected schools.

4.6.3 WITHIN SCHOOL SAMPLING

The Heads of Education Committee (HEDCOM) had agreed to the TIMSS testing programme on condition that only intact classes were to be tested (see earlier comment). Thus a simple randomizing programme was developed to select the class or grade to be tested in each of the sampled schools.

4.6.4 ADVANCE DATA FROM SCHOOLS

The preliminary questionnaires sent to schools resulted in a return of less than 60 per cent after seven months of follow-up correspondence. Class lists were, in many cases not available or had to be regarded as unreliable. Thus, on occasion, test administrators arrived at schools with inadequate knowledge about these schools. This lack of information was to complicate the TIMSS - South Africa programme considerably. All of these factors militated against meeting the TIMSS requirement of at least 85 per cent of first choice schools. The failure to collect this required information had the effect that TIMSS - South Africa were not able to prepare Class Tracking and Student Tracking forms. Student-Teacher Linkage forms could only be partially constructed after the testing had been completed.

4.6.5 PERFORMANCE TESTING

In addition to the age-determined population studies, the TIMSS Curriculum Framework (see Tables 4.2 and 4.3 earlier in this chapter) of interest also included an aspect of Performance testing in the form of a 'travelling' carousel of practical/experimental work. This was directed at both Populations 1 and 2. The sample requirements and number of students to be tested were considerably reduced for the stipulations of the 'paper' test requirements. South Africa was unable to participate in this aspect of the programme on the grounds of cost, staffing and time constraints.

4.7 PROBLEMS ENCOUNTERED BY TEST ADMINISTRATORS

It was at the testing stage that the difficulties of the field operations of TIMSS commenced. The testing agents found amongst other problems, that:

- at least two schools in the sample did not, in fact, appear to exist at the physical addresses on record;

- four schools had arbitrarily changed their names and then could no longer be part of the agreed sample;

- several schools refused to admit the testing personnel;

- many schools confirmed arrangements and then declined to co-operate;

- at least two schools were not accessible by road;

- in spite of the training, at least one test administrator tested two schools which were not on the sample list, nor were they on either of the reserve lists;

- in one of the schools, it was apparent that the class teacher, and not the students, had answered the entire set of test papers;

- in another school, the Principal would not permit the testing of only a single class. This principal's attitude was 'test one - test all'. The consequence of this action was that half the school answered the test papers and the other half answered the questionnaires.

- in yet another of the schools, the Students' Representative Council demanded a payment before they would permit the tests to be written. This school was not tested.

- Often visits were made without prior arrangements being agreed upon due to the poor communication systems already commented upon.

- About fifteen per cent of Afrikaans medium schools in the sample refused to participate.

4.8 THE REALIZED SOUTH AFRICAN SAMPLE

The final returns of test papers and questionnaires from the sampled schools is shown below in Table 4.12. In total, the schools realized and the schools finally accepted by TIMSS showed these discrepancies.

	Realized Schools	Accepted by TIMSS
Standard 5 Classes	88 %	81%
Standard 6 Classes	76 %	71%

The failure to achieve a return of 85 per cent of first choice schools explains the fact that although South Africa is fully reported on in the final international reports, it was not ranked. A detailed discussion of the reporting policies of TIMSS is provided in Chapter 5.

This failure to meet the pre-set targets of schools to be realized was largely due to local and provincial administrative problems (as already detailed in 4.7), rather than problems inherent in the TIMSS test and questionnaire materials.

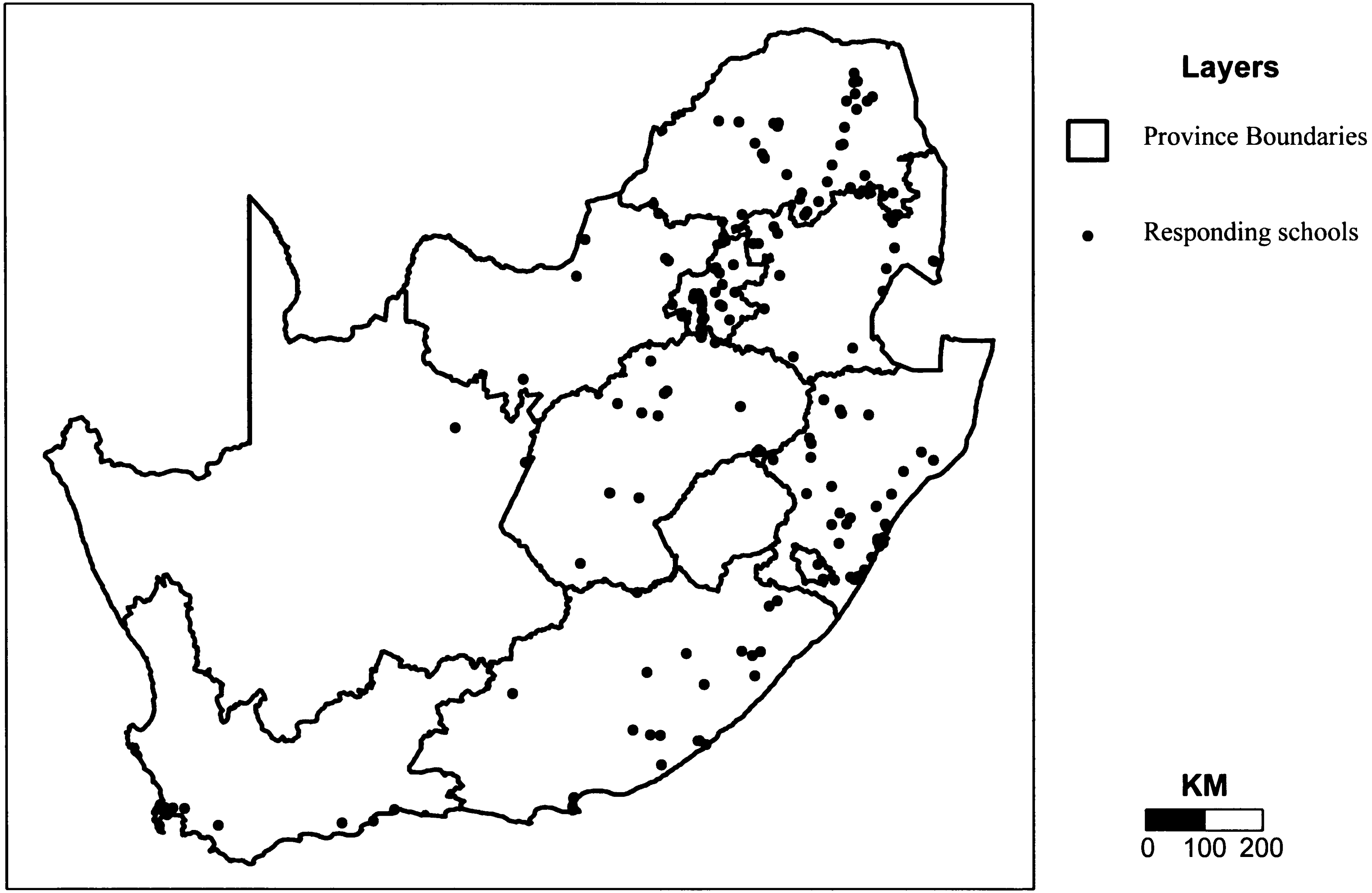
Table 4.12 The realized sample of schools related to the original sample

PROVINCE	Primary Schools Std 5	Middle Schools Stds 5 & 6	Secondary Schools Std 6	Std. 5 Returns	Std 6 Returns	TOTAL Selected Realised
Eastern Cape Province	13	13	19	20	16	45 36
Free State Province	6	3	11	8	9	20 17
Gauteng Province	19	2	18	20	18	39 38
KwaZulu-Natal Province	33	1	32	29	21	66 50
Mpumalanga Province	11	-	13	8	13	24 21
Northern Cape Province	2	-	2	1	1	4 2
Northern Province	24	2	26	23	21	52 44
North West Province	-	14	-	14	12	14 26
Western Cape	11	1	11	10	4	23 14
TOTALS	119	36	132	133	115	287 300 classes 248
% Returns⌖				88%	76%	82.7%

⌖ This percentage is higher than the percentage accepted by TIMSS Study Centre because of the middle schools in provinces other than the North West Province in which two classes were tested. These classes were additional to the required sample. The TIMSS approved returns were: Standard 5 = 81% and Standard 6 = 70%.

The distribution of the realized sample schools is shown over the page on Map 4.2.

Distribution of TIMSS population 2 sample schools



4.9 ANALYSIS OF THE TESTING PROCESS AND BOOKLETS

4.9.1 THE TIMING AND LENGTH OF THE TESTS

The final draft of the TIMSS test papers shows the following analysis in terms of time requirements for the test. (Test administrators were given the option of allowing an extra thirty minutes for slow finishers. In view of the anticipated language difficulties that would be encountered by second or third language speakers, all South African students were allowed a full two hours.)

Table 4.13 Estimated time required for student responses

ITEM TYPE	TIME (minutes)
Multiple choice	1
Short answer	2
Extended response	5

Table 4.14 The estimated time for the duration of the tests

	Multiple Choice	Short Answer	Extended Answer	TOTAL TIME
Test book 1	63	4	20	87 mins
Test book 2	62	2	25	89 mins
Test book 3	63	4	20	87 mins
Test book 4	62	1	25	88 mins
Test book 5	58	5	25	88 mins
Test book 6	63	4	20	87 mins
Test book 7	61	5	20	86 mins
Test book 8	58	9	25	92 mins

4.9.2 THE INTERNATIONAL POOL OF QUESTIONS

Early in the planning stages of TIMSS, it was appreciated that within the large spread international curricula, a technique would have to be developed to test, on a national sample basis, far more material than any single student would be able to handle in the ninety minutes allocated to testing. Accordingly a programme and an International Testing Committee was established in mid 1993 in order to :

- compile a large range of test items from participating countries that were compatible with the curriculum analysis coding guide;
- operate internationally based trials on this initial material to establish the academic and statistical validity for each item; and
- condense this material into a series of question clusters from which meaningful and effectively equivalent test booklets could be compiled.

4.9.2.1 Question clusters - content and design of specification tables

A specification table containing five types of questions clusters was designed to control the distribution of Mathematics and Science questions between the test books and to control the proportions of students answering each type of question .

- Type 1 Cluster - This was the Core Cluster common to all eight of the Population 2 test books. This was Cluster A. The whole of the South African sample population wrote these questions

- Type 2 Clusters - These were intended to be Focus Clusters, labled B to H. These clusters are rotated through the eight test booklets. Three of these clusters appeared in each test booklet.

- Type 3 Clusters - These are Breadth Clusters. These clusters are labled I to M. Each of these clusters appears in only one test booklet.

- Type 4 clusters - These are Free Response clusters interspersed with multiple choice questions. These clusters are labled N to R.

- Type 5 Clusters - Labled S to Z are with the exception of one question (added to balance the time allocations per cluster) all Free Response Item questions.

4.9.2.2 The layout of the TIMSS - Pop2 test booklets

The table below (4.15) shows the order of clusters in each of the eight test booklets; and the table that follows (4.16) shows the distribution of the question clusters in each of these test books.

Table 4.15 The distribution of question clusters in test booklets

NOTE: The Test Booklets are made up of seven question clusters with the exception of Test Booklet 8 which contains five question clusters.

CLUSTER → ↓ BOOKLET							
1	B	A	C	S	E	I	T
2	C	A	D	W	F	J	X
3	D	A	E	T	G	K	U
4	E	A	F	X	H	L	Y
5	F	A	G	U	B	M	V
6	G	A	H	Y	C	N	Z
7	H	A	B	V	D	O	W
8	B	A	Q	*	R	P	*

It was agreed at a National Research Co-ordinators' meeting that there should be a common question cluster that would appear in all the test books to allow statistical cross-referencing between the books. To reduce the possibilities of cheating, this common cluster, cluster A (shaded), was placed as the second cluster in each book.

Table 4.16 The distribution and sequencing of question clusters within the test booklets

TEST BOOKLET ➔ 🡻 CLUSTER	1	2	3	4	5	6	7	8
CLUSTER A	2	2	2	2	2	2	2	2
CLUSTER B	1				5		3	1
CLUSTER C	3	1				5		
CLUSTER D		3	1				5	
CLUSTER E	5		3	1				
CLUSTER F					1			
CLUSTER G		5		3		1		
CLUSTER H			5		3	3	1	
CLUSTER I	6							
CLUSTER J		6						
CLUSTER K			6					
CLUSTER L				6				
CLUSTER M					6			
CLUSTER N						6		
CLUSTER O							6	
CLUSTER P								6
CLUSTER Q								3
CLUSTER R								5
CLUSTER S	4							
CLUSTER T	7		4					
CLUSTER U			7		4			
CLUSTER V					7		4	
CLUSTER W		4					7	
CLUSTER X		7		4				
CLUSTER Y				7		4		
CLUSTER Z						7		

The clusters are rotated between the booklets so that, where desired, a country would have the data available to analyse the effect of position in the test on performance for any particular question or group of questions. With the exception of Booklet 8, all the booklets are reasonably equivalent in terms of degree of difficulty. However, in Booklet 8, there are two less clusters and an excess of Free Response Items, which makes this test book marginally more difficult. In view of this apparent discrepancy it is worth emphasizing again that TIMSS is

intended to generate a National view of Mathematics and Science education. TIMSS is not designed to provide valid data for schools and individual students nor for individual test books.
With few exceptions (clusters A to I), each cluster contains a mix of Mathematics and Science questions.

Table 4.17 The distribution of Mathematics and Science questions in the clusters.

CLUSTER	Mathematics	Science	TOTAL
A	6	6	12
B	6	6	12
C	6	6	12
D	6	6	12
E	6	6	12
F	6	6	12
G	6	6	12
H	6	6	12
I	9	10	19
J	9	9	18
K	9	10	19
L	9	8	17
M	9	5	14
N	9	10	19
O	9	8	17
P	9	8	17
Q	10	8	18
R	9	5	14
S	2	-	2
T	2	-	2
U	2	-	2
V	4	-	4
W	-	2	2
X	-	2	2
Y	-	2	2
Z	2	-	2
TOTAL	151	135	286

4.9.2.3 Free Response Items

In addition to the traditional Multiple Choice Questions, it was agreed that approximately 25 per cent of the questions should be Free

Response Items [FRI]. The intention of these FRIs is to give the students opportunity to 'express themselves more freely and to provide some insight into how school students think in a scientific context' (Schmidt, 1993: np). Supporting this view, Hoy & Gregg (1994: 174) emphasize the distinction between the skills required in answering multiple choice questions and those requiring more demanding responses:

> Many standardized tests require responses at the recognition level or below. In contrast, students are often required to produce recall or formulation [cf. FRI] responses ....

Underlining the importance of learning theory (discussed in Chapter 2) it is essential that teachers consider response types. For example, multiple choice questions of low performance expectation type require only recognition, whereas higher order multiple choice questions and FRIs are much more demanding and diagnostic in terms of the wide variety of possible responses. Thinking about response types can help to explain discrepancies between Standardized Test scores (usually multiple choice format) and classroom performance.

The nature and results of the Free Response Items are discussed more fully in Chapter 5.

4.9.2.3.(a) Coding Free Response Items

Free Response Items are coded with a two figure code.

- the first figure indicates the degree of correctness and,
- the second figure indicates the method or error the student had made.

Table 4.18 Free Response Items - codes allocated

FIRST DIGIT		SECOND DIGIT	
3	Completely Correct	0	
		1	Alternative methods
		2	
2	Partially Correct	3	
		4	Misconceptions
		5	
1	Somewhat correct	6	Repeats information
		7	
		8	National Options
7 for (0)	Completely Incorrect		
9	Off task	9	Other

An example of a typical FRI and the coding instructions for question N7 were as follows:

Table 4.19 Codes provided for Question N7

QUESTION N 7
When a glass jar is placed over a lighted candle the flame goes out. Why does this happen?

CODE	RESPONSE (Answers are given for each case
1 0	Refers to the need for oxygen
1 1	Refers to the need for air
1 2	Refers to the need for air using non-scientific language
1 9	Other correct
7 0	Refers to its getting too hot
7 1	States that the gas/smoke/vapour/carbon dioxide is trapped in the jar
7 2	Refers to the properties of the glass
7 6	Merely repeats the information in the stem
7 9	Other incorrect
9 8	Illegible/Erased/Crossed out
9 9	Blank

In the question shown, the student was able to obtain 1 or 0 marks for correctness which varied from question to question and then the codes for typical errors and no responses are shown (Some of the FRI questions carried up to 3 marks).

Thus if a subsequent frequency analysis were carried out both marks and the frequency of errors types can be calculated.

4.10 EVALUATION OF THE CURRICULUM ANALYSIS PROCEDURE

The very nature of curriculum analysis and the labelling of small content sections lends itself to comparisons between curricula. The frequency with which a code sequence appears in an analysis gives an indication of the depth to which and intensity with which a particular section of the syllabus is taught. Repetition of codes also makes it possible to evaluate the 'spiral' revisitation component of a curriculum in succeeding years of schooling. In the same manner, codes that appear in one curriculum and not in another can lead to examination of these 'missing' items and a re-evaluation of such omissions. Curriculum analysis by coding blocks or sections and various comparisons also provide a method of continuous monitoring of developments and changes on an international or provincial basis. The TIMSS curriculum analysis has already revealed several topics which are, at once, effectively universal but completely absent from South African curricula.

Another aspect of curriculum analysis that should have an impact on South African education is the process of examining the internal structure of textbooks. The structures examined above suggest that rather than a teaching/learning aid this book is an exercise/algorithm practice book with some added value.

It can be conjectured that if final draft print proofs of a new textbook were to undergo this type of analysis and subsequent structural revision be made before publication, the quality and usefulness of South African texts would improve for relatively little effort on the part of publishers and textbook approval committees.

4.11 COMMENTARY ON FINAL DATA SUBMITTED

4.11.1 DATA CLEANING CYCLES

In the process of data cleaning, approximately one thousand two hundred inadequate or faulty test sets were rejected. Identified deficiencies include:

- Repetition of similar answers e.g. A, A, A, A, or B, B, B, B, etc.
- Repeating cyclic answers e.g. A, B, C, D, E, etc.
- Matching of individual questionnaires to Test Papers. Any non-matching booklets were rejected.
- A sample of the returns were scanned for similar answer sequences from the same schools.
- The questionnaires were scanned for answers that exceeded the extreme limits prescribed by the data capture spreadsheet.
- It was discovered late in the testing process that about four hundred of the Test Book 5 had been incorrectly bound, and two pages were missing. These faulty books were, insofar as possible, withdrawn.During the data cleaning process the balance were recovered by a data search and these too were rejected.
- Test books or questionnaires with a substantial proportion of unanswered or erroneously answered questions were also rejected.

This data checking and cleaning of the South African data set, locally and in Hamburg, left 9 987 Standard 5 and 6 matched student test papers and student questionnaires. The data from this set of students is analysed in Chapters 5 and 6.

4.12 A RETROSPECTIVE ON THE TIMSS METHODOLOGY

4.12.1 NATIONAL QUALITY CONTROL MONITOR'S REPORT AND THE SOCIO-POLITICAL ENVIRONMENT

The TIMSS Study Centre appointed a National Quality Control Monitor to oversee a part of the TIMSS testing process. In conjunction with the internationally standardized Test Administration format and Test Co-ordinator's manual, this was intended to add to the credibility of TIMSS.

The South African Quality Control Report (NQM Report, 1995: 2) concludes that:

> In my opinion the testing that I have observed is a close representation of Mathematics and Science education in South Africa.

Notwithstanding being prevented from attending several observations because of school and/or other local disturbances, this report thus provides an overall ratification of TIMSS.

4.12.2 LACK OF A NATIONAL INFRASTRUCTURE AND LACK OF TECHNOLOGY IN DEVELOPING COUNTRIES

In the field of technology, discrepancies between the expectations of Developed countries and the realities of the situation in Developing countries are marked. For example, it was assumed that schools could and would communicate data. The existence of comprehensive class lists was also an assumed asset. Other difficulties, such as the absence of telephones or of the ability to transmit even simple messages without the aid of sophisticated technology over distances in excess of 300 km, could not be envisaged. A postal service that required six to eight weeks before a reply could be obtained, assuming that such a reply was forthcoming, was incomprehensible. There was a general assumption that road transport to schools would be efficient and smooth. In South Africa, however, it is a well documented fact that this is not the case and the local transport problems were exacerbated by the loss of two vehicles.

The lack of availability of computer hardware, before compromises were reached, was severely damaging both to morale and to local time schedules. Similarly, the cost of attending NRC meetings was viewed in dollar terms and not in terms of a rapidly depreciating Rand. In South Africa's case, this meant that attending all the international meetings became prohibitive.

Another drawback was the lack of orientation courses for latecomers to the TIMSS programme. There was no comprehensive list of TIMSS publications that could be used either to confirm that documentation was complete or ascertain what items were missing.

4.12.3 ADDED VALUE IN TERMS OF NEW TECHNOLOGY AND HUMAN RESOURCE DEVELOPMENT [HRD] AND EDUCATION TECHNOLOGY

In terms of added value and Human Resource Development, TIMSS - South Africa has compiled what is probably the largest data base existent on Mathematics and Science education and achievement.

During the three years of TIMSS no less than one hundred and eighty persons have received training in data capture, Free Response Item [FRI] coding, curriculum analysis and other aspects of TIMSS requiring the attention of larger numbers of personnel over short periods of time. There are thus many aspects of TIMSS that may or should have a lasting impact on South African education.

4.12.4 NATIONAL PROFILES

In the sixth edition of *Measurement and Evaluation in Teaching*, Gronlund and Linn (1990: 468) express the public's concern about testing:

> Decisions about selection, administration and use of educational tests are no longer left to the educator alone: The public has become an active and vocal partner.

These factors have led some countries to institute mandatory assessment programmes to satisfy public demand for evidence of the effectiveness of a school's programme. In South Africa, this kind of testing is not legislated. Public concern is focused more on the social consequences of testing, such as discrimination and bias, and on the consequences for the individual, such as anxiety and damage to self-esteem.

By contrast the TIMSS testing programme is, as can be seen by the arguments in this chapter, one which seeks to bypass such concerns by providing census-like data for reporting to the public on the educational progress of the participating countries at large. TIMSS is a 'low stakes' test offering a national profile of method and outcomes. As already noted, TIMSS provides no individual or school scores of educational measurement.

4.12.5 TIMSS MANAGEMENT DOCUMENTS

This chapter describes TIMSS in South Africa and extensive and obligatory use has been made of the numerous TIMSS documents, guides and instruction manuals issued by the Study Centre in Boston. The titles of the principal documents are listed in the bibliography.

CHAPTER 5

AN ANALYSIS OF SOUTH AFRICAN PERFORMANCE IN THE TIMSS ACHIEVEMENT TEST PAPERS

5.1 AN OUTLINE AND OVERVIEW OF THE ANALYSIS OF OUTCOMES

As was announced at the TIMSS International press release on 21 November 1996 in Washington DC and at the South African press release on 26 November 1996 in Johannesburg, South Africa's achievement in this recent international study was appreciably lower than that of the second lowest scoring country, Colombia. South Africa, in the international rankings for the Upper Grade Mathematics, scored 354 compared to Colombia's 385; and 348 compared to Colombia's 369 in the Lower Grade Mathematics. In the Science achievement rankings South Africa scored 326 and 317 compared to 387 and 411 for Colombia in the Upper and Lower Grades respectively. The *Sunday Times* (1996:1) phrased it in this way:

> Of the 41 countries, developing and developed, whose data met the stiff standards of the project - known as the Third International Mathematics and Science Study - South Africa was at the bottom of the class in every category, its teenagers woefully equipped for the demands of a hi-tech global economy.

Reviewing this extract, the point that South Africa participated in TIMSS as the only representative from the African continent is not commented on, neither is the fact that some 30 per cent of the countries that indicated their intention to participate in TIMSS failed to complete the process. Perhaps most importantly though, the press reactions to the TIMSS announcement failed to recognize that, for the first time, South Africa was in possession of baseline data from which new dispensations in Mathematics and Science Education could be evaluated.

In this chapter, the process of analysis of the South African performance in TIMSS is based on:

- an analysis of the test papers in terms of what levels of intellectual performances are expected from the students;
- the degree to which the South African Mathematics and Science curricula fitted the range of content expected in the TIMSS questions;
- overall national rankings of the participating countries;
- pairs or small groups of similar questions for which performance is compared and contrasted with those of selected other countries.

The rationale for selection of questions and question pairs has been based on a representative selection from each of the fields of Mathematics and Science. Attention has been paid to those questions which appear to exhibit responses which indicate the possibility of 'universal' misconcepts and those of particular and specific interest in that they reveal general flaws or weaknesses in mathematical processes and scientific thinking by the students in the sample.

Thereafter deductions are extrapolated from the statistical data and, where appropriate, evaluative comments and/or cross references to learning theory (discussed earlier in Chapter 2) are made.

5.2 EMBARGOED QUESTIONS

Numerous questions, including all those in Clusters A to H have had a TIMSS embargo placed on them to preserve confidentiality for future use. Where it is informative to refer to these questions in this chapter, no explicit statement of the question will be given and only general content and expectations are described in outline.

5.3 RANGE AND DISTRIBUTION OF PERFORMANCE EXPECTATIONS

The TIMSS test books are constructed on a spectrum of performance expectations, ranging from recall of knowledge to higher order problem solving situations. There are also Free Response Items [FRIs] which, as already defined in Chapter 1, are open ended. With this type of question, there is the possibility of more than one method of reaching an answer and in some cases more than one possible correct answer. The tables below (Tables 5.1 and 5.2) provide an outline of performance expectations from Mathematics and Science questions and their distribution.

5.3.1 THE TIMSS COGNITIVE DOMAINS

The TIMSS expectations, as shown in the tables below, are analogous in some ways to the well known and classical Bloom's Taxonomy of Educational Objectives (Gronlund & Linn, 1990: 506), which is set out in Table 5.1 below. The correlation between Bloom's Taxnomy and the TIMSS performance expectations is illustrated in Tables 5.2 and 5.3.

Table 5.1 TIMSS Performance expectations compared with Bloom's Taxonomy of Educational Objectives.

BLOOM	TIMSS MATHEMATICS	TIMSS SCIENCE
Knowledge	Knowing	
Comprehension		Understanding simple and complex information
Application	Using routine and complex procedures	Investigating the Natural world
Analysis	Problem solving	Theorizing/Analyzing
Synthesis		Tools/Processes

Table 5.2 Performance expectations of the TIMSS questions - Mathematics

Subject Field → Performance Categories ↓	Fractions Number Sense 34%	Geometry 15%	Algebra 18%	Data Rep. Analysis / Probability 14%	Measure-ment 12%	Proportion-ality 7%	Totals 100% / 100%
Knowing	10	5	6	4	4	2	32 22%
Using Routine Procedures	12	6	7	5	4	3	38 25%
Using Complex Procedures	11	5	5	5	4	2	32 21%
Solving Problems	17	8	9	7	6	4	51 32%
TOTAL	50	24	27	21	18	11	151 100%

Table 5.3 Performance expectations of the TIMSS questions - Science

Subject Field Performance Category	Earth Sciences 16%	Life Sciences 30%	Physics 30%	Chemistry 14%	Environment/ Nature of Science 10%	TOTALS 100% / 100%
Understanding Simple Information	9	16	16	8	5	54 40%
Understanding Complex Information	6	12	12	5	4	39 29%
Theorizing / Analyzing	5	8	8	4	3	28 21%
Tools / Processes	1	3	2	1	1	8 6%
Investigating the Natural World	1	1	2	1	1	6 4%
TOTALS	22	40	40	19	14	135 100%

This wide ranging testing of abilities emphasizes the potentially large number of relatively independent factors that the TIMSS methodology uses to describe the dimensions of human abilities that are regarded as significant for assessment in Mathematics and Science.

Although the tables above (Tables 5.1 and 5.2) also reflect the two broad categories of theories of learning discussed in Chapter 2 of this thesis: the factual and the cognitive and problem solving, these performance expectations can be seen as 'deficient' in the sense that the tasks are not designed to take cognizance of learning 'disabilities' attributable to such factors as inexperience, cultural bias and language difficulties. As Hoy and Gregg (1994: 17) assert:

> Attention to the dialogic dynamics of the learning experience and sensitivity to the role of the learners' characteristics as mediators to problem solving should become the focus of the evaluation process.

5.4 CURRICULUM FIT

All participating nations were required to carry out a 'curriculum fit' analysis to establish the degree of overlap between national/local curricula and the broad field of Mathematics and Science covered by the TIMSS question bank. The underlying intention is to examine the performance of various populations on those items which 'fitted' the national curriculum and those that lay outside the national curriculum. South Africa's degree of curriculum fit with the range of TIMSS questions is shown below in Table 5.3. A complete exposition of the curriculum fit of all the two hundred and eighty-six TIMSS questions is shown in Appendix 4.

Table 5.4 The degree of 'fit' between the South African curriculum and the range of the TIMSS questions

Standard	Subject	Curriculum Fit Percentage
Standard 5	Mathematics	58%
Standard 6	Mathematics	80%
Standard 5	Science	18%
Standard 6	Science	51%

5.4.1 CURRICULUM FIT - MATHEMATICS AND SCIENCE

An analysis of the one hundred and fifty-one Mathematics questions in the eight TIMSS test forms indicates the above division of questions between those that cover material within the South African curricula and those which lie outside South African curricula.

Whilst no official figures have been published, in most participating countries the Standard 5 curriculum fit for both Mathematics and Science lies within the range of 55-60 per cent and the Standard 6 curriculum fit lies in the range of 75-85 per cent. As is commented on later in this chapter, curriculum 'fit' performance as opposed to curriculum 'no fit' performance appears to have little influence on the results of a number of the countries that participated in TIMSS. This aspect is discussed further in Chapter 7.

Compared to other nations that participated in the Population 2 of the TIMSS study, the curriculum fit for South African Mathematics is reasonably conformable. Notwithstanding the identified 'gaps', this evidence of a high level of curriculum fit suggests that in the field of Mathematics, South African curricula in the middle years of schooling are clearly in line with the wider international developments. With curriculum development programmes currently in progress in South Africa, omitted fields as well as fields of Mathematics with poor coverage in terms of the TIMSS questions become points for consideration for inclusion in any new curricula.

Compared to other nations that participated in the Population 2 of the TIMSS study, this curriculum fit for Science of 17.7 per cent with the Standard 5 curriculum is very low. At the Standard 6 level, South African curricula are also clearly at variance with international developments and tendencies. Omissions, such as that of Human Biology (fields in which there is a zero fit), and other in fields where there is only a low level of curriculum fit may well be worthy of consideration for inclusion in any new curricula developed in South Africa. Similarly Earth Science should be considered very seriously, particularly in view of the dependence of the South African economy on Mining.

5.5 OVERALL NATIONAL RANKINGS

5.5.1 PRESENTATION

The nations that participated in TIMSS and which are reported in the final International Reports (TIMSS: 1996 (a) and (b)) are recorded in five bands that are descriptive of the level to which the countries attained the standards set by the TIMSS Study Centre.

BAND 1 - This band shows those nations, as shown in Tables 5.5 to 5.8, which met all the TIMSS requirements with regard to realization of their sample schools and supporting records.

BAND 2 - These countries did not meet the required 85 per cent participation rate of first drawn sample schools. Some use was made of replacement schools.

BAND 3 - Band 3 countries did not meet the age range specifications in that there was a substantial proportion of older students.

BAND 4 and BAND 5 - Countries with unapproved sampling procedures at the classroom level are classified as Band 4. South Africa was unranked and therefore placed in Band 4 because there was only 48.7 per cent of thirteen year old students in the selected grades. Also several substitute schools had to be used and the test administrators were unable to obtain a meaningful number of class lists and teachers' identities from the selected schools.

A number of countries, for example, Switzerland, Denmark and Porto Rico are unreported in part or only reported as appendices. Mexico withdrew its data from the international reports at a very late stage in the TIMSS programme.

5.5.2 THE INTERNATIONAL RANKINGS OF THE REPORTED NATIONS

The scores and ranking of nations' achievements are based on Item Response Theory which is a statistical technique that allows plausible scores to be estimated with some confidence on questions not actually written by the candidates to be estimated. The national scores shown, for both Mathematics

(TIMSS, 1996(h): 21) and Science (TIMSS, 1996(i): 21), are based on a mean of 500 and a Standard deviation of 100.

Table 5.5 Overall international rankings - Mathematics - Lower Grade

LOWER GRADE = South Africa - Standard 5

	COUNTRY	MEAN ACHIEVEMENT	Average Age of Sample(yrs)
BAND 1	1. Singapore	601	13.3
	2. Korea	577	13.2
	3. Japan	571	13.4
	4. Hong Kong	564	13.2
	5. Belgium (Fl)	558	13.0
	6. Czech Republic	523	13.4
	7. Slovak Republic	508	13.3
	8. Belgium (Fr)	507	13.2
	9. Switzerland	506	13.1
	10. Hungary	502	13.4
	11. Russian Federation	501	13.0
	12. Ireland	500	13.4
	13. Canada	494	13.1
	14. France	492	13.3
	15. Sweden	477	12.9
	16. England	476	13.1
	17. United States	476	13.2
	18. New Zealand	472	13.0
	19. Scotland	463	12.7
	20. Latvia	462	13.3
	21. Norway	461	12.9
	22. Iceland	459	12.6
	23. Spain	448	13.2
	24. Cyprus	446	12.8
	25. Lithuania	428	13.4
	26. Portugal	423	13.4
	27. Iran	401	13.6
BAND 2	Australia	498	13.2
	Austria	509	13.3
	Bulgaria	514	13.1
	Netherlands	516	13.2
BAND 3	Colombia	369	14.5
	Germany	484	13.8
	Romania	454	13.7
	Slovenia	498	13.8
BAND 4	Denmark	465	12.9
	Greece	440	12.6
	South Africa	348	13.9
	Thailand	495	13.5

INTERNATIONAL AVERAGE FOR MATHEMATICS ACHIEVEMENT - LOWER GRADE [Std.5]= 484

(Mathematics Achievement in the Middle School Years, TIMSS, 1996(h))

Table 5.6 Overall international rankings - Mathematics - Upper Grade

UPPER GRADE - South Africa = Standard 6

	COUNTRY	MEAN ACHIEVEMENT	Average Age of Sample(yrs)
BAND 1	1. Singapore	643	14.5
	2. Korea	607	14.2
	3. Japan	605	14.4
	4. Hong Kong	588	14.2
	5. Belgium (Fl)	565	14.1
	6. Czech Republic	564	14.4
	7. Slovak Republic	547	14.3
	8. Switzerland	545	14.2
	9. France	538	14.3
	10. Hungary	537	14.3
	11. Russian Federation	535	14.0
	12. Ireland	527	14.4
	13. Canada	527	14.1
	14. Sweden	519	13.9
	15. New Zealand	508	14.0
	16. England	505	14.0
	17. Norway	503	13.9
	18. United States	500	14.2
	19. Latvia	493	14.3
	20. Spain	487	14.3
	21. Iceland	487	13.6
	22. Lithuania	477	14.3
	23. Cyprus	474	13.7
	24. Portugal	454	14.5
	25. Iran	428	14.7
BAND 2	Australia	530	14.2
	Austria	539	14.3
	Belgium (Fr)	526	14.3
	Bulgaria	540	14.0
	Netherlands	541	14.3
	Scotland	498	13.7
BAND 3	Colombia	385	15.7
	Germany	509	14.8
	Romania	482	14.6
	Slovenia	541	14.8
BAND 4	Denmark	502	13.9
	Greece	484	13.6
	Thailand	522	14.3
BAND 5	Israel	522	14.1
	Kuwait	392	15.3
	South Africa	354	15.4

INTERNATIONAL AVERAGE FOR MATHEMATICS ACHIEVEMENT - UPPER GRADE [Std.6] = 513

(Mathematics Achievement in the Middle School Years, TIMSS, 1996 (h))

Table 5.7 Overall international rankings - Science - Lower Grade

LOWER GRADE - South Africa = Standard 5			
	COUNTRY	MEAN ACHIEVEMENT	Average Age of Sample(yrs)
BAND 1	1. Singapore 2. Korea 3. Czech Republic 4. Japan 5. Belgium (Fl)	545 535 533 531 529	13.3 13.2 13.4 13.4 13.0
	6. Hungary 7. England 8. Slovak Republic 9. United States 10. Canada	518 512 510 508 499	13.4 13.1 13.3 13.2 13.1
	11. Hong Kong 12. Ireland 13. Sweden 14. Russian Federation 15. Switzerland	495 495 488 484 484	13.2 13.4 12.9 13.0 13.1
	16. Norway 17. New Zealand 18. Spain 19. Scotland 20. Iceland	483 481 477 468 462	12.9 13.0 13.2 12.7 12.6
	21. France 22. Belgium (Fr) 23. Iran 24. Latvia 25. Portugal 26. Cyprus 27. Lithuania	451 442 436 435 428 420 403	13.3 13.2 13.6 13.3 13.4 12.8 13.4
BAND 2	Australia Austria Bulgaria Netherlands	504 519 531 517	13.2 13.3 13.1 13.2
BAND 3	Colombia Germany Romania Slovenia	387 499 452 430	14.5 13.8 13.7 13.8
BAND 4	Denmark Greece South Africa Thailand	439 449 317 493	12.9 12.6 13.9 13.5
INTERNATIONAL AVERAGE FOR SCIENCE ACHIEVEMENT - LOWER GRADE [Std.5]= 479			

(Science Achievement in the Middle School Years, TIMSS, 1996 (i.))

Table 5.8 Overall international rankings - Science - Upper Grade

UPPER GRADE - South Africa = Standard 6			
	COUNTRY	MEAN ACHIEVEMENT	Average Age of Sample(yrs)
BAND 1	1. Singapore	607	14.5
	2. Czech Rep.	574	14.4
	3. Japan	571	14.4
	4. Korea	565	14.2
	5. Hungary	554	14.3
	6. England	552	14.0
	7. Belgium	550	14.1
	8. Slovak Republic	544	14.3
	9. Russian Federation	538	14.0.
	10. Ireland	538	14.4
	11. Sweden	535	13.9
	12. United States	534	14.2
	13. Canada	531	14.1
	14. Norway	527	13.9
	15. New Zealand	525	14.0
	16. Hong Kong	522	14.2
	17. Switzerland	522	14.2
	18. Spain	517	14.3
	19. France	498	14.3
	20. Iceland	494	13.6
	21. Latvia	485	14.3
	22. Portugal	480	14.5
	23. Lithuania	476	14.3
	24. Iran	470	14.6
	25. Cyprus	463	13.7
BAND 2	Australia	545	14.2
	Austria	558	14.3
	Belgium (Fr)	471	14.3
	Bulgaria	565	14.0
	Netherlands	560	14.3
	Scotland	517	13.7
BAND 3	Colombia	411	15.7
	Germany	531	14.8
	Romania	486	14.6
	Slovenia	560	14.8
BAND 4	Denmark	478	13.9
	Greece	497	13.6
	Thailand	525	14.3
BAND 5	Israel	524	14.1
	Kuwait	430	15.3
	South Africa	326	15.4
INTERNATIONAL AVERAGE FOR SCIENCE ACHIEVEMENT - UPPER GRADE [Std.6] = 516			

(Science Achievement in the Middle School Years, TIMSS, 1996 (i))

5.5.2.1 Commentary on the ranking tables

As can be seen from the four international ranking tables above, the Oriental countries (Hong Kong, Singapore, Korea and Japan) all performed considerably above average. It is noticeable that the Czech Republic and to a slightly lesser extent the Slovak Republic also did well especially considering their turbulent history since the outbreak of the Second World War. Of the developing countries, South Africa, Thailand, Iran and Colombia that were finally reported on, only Thailand performed well in all four reporting fields (Upper and Lower Grade Mathematics and Upper and Lower Grade Science). According to newspaper reports (*Sunday Times*, 1996: 1), the United States performance is quoted as a 'National Disaster'. Overall, in terms of ranking, the USA shows little change from the SIMSS findings several years ago. This is despite President Bush's stated aim made in 1988, echoing President Kennedy's 1958 'man on the moon' speech, that America would be top of the international rankings in Mathematics and Science by the year 2000. This latter goal will, patently, not be realized. Whilst this 'national disaster' comment may seem extravagant, education in the United States of America is an issue relating both to national pride and to local, state and national politics. From discussion at various TIMSS meetings, the ranking process was of dominant importance to the United States but less so to the majority of the European nations. From South Africa's point of view, access to South African data and international data would appear to be far more important and useful than the ranking information. As already stated in the opening paragraphs of this chapter, South Africa's performance in all the four reporting lists is bottom. Despite this poor national performance, it has been and will be instructive to examine South African findings closely both for economic and academic reasons.

The ranking tables above (5.5 - 5.8) show that, with the exception of Colombia (15.7 years), South Africa (15.4 years) has the highest average

age for Upper Grade students who wrote the TIMSS test papers. In the Lower Grade classes, South Africa's average age (13.9 years) is again the second oldest but the age differential between South Africa and the other countries does not appear to be so great. It can be hypothesized that these factors are due, in part, to the late entry into Grade 1 in South Africa and to a number of students repeating Grade 8 in secondary school.

5.5.3 PERFORMANCE BY SUBJECT FIELD - MATHEMATICS

The Tables below, Tables 5.9 - 5.12, show the South African performance breakdown within the Mathematics and Science subject fields. For the purposes of comparison, the South African overall national average and the achievements of Colombia and Iran in these fields are also shown. It is noticeable that the rank sequences do not change from field to field in either Mathematics or Science.

Table 5.9 Standard 5 Mathematics performance

KEY to Tables 5.3 to 5.10 1 = South Africa 2 = Colombia 3 = Iran

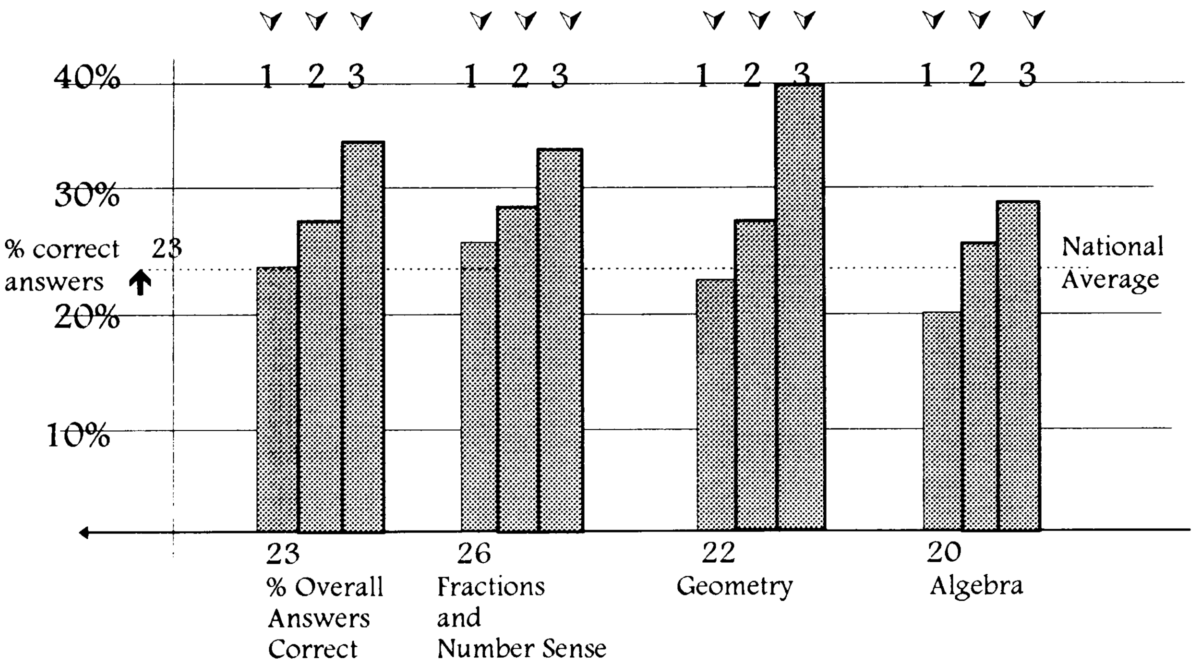


Table 5.9 Standard 5 Mathematics performance (continued)

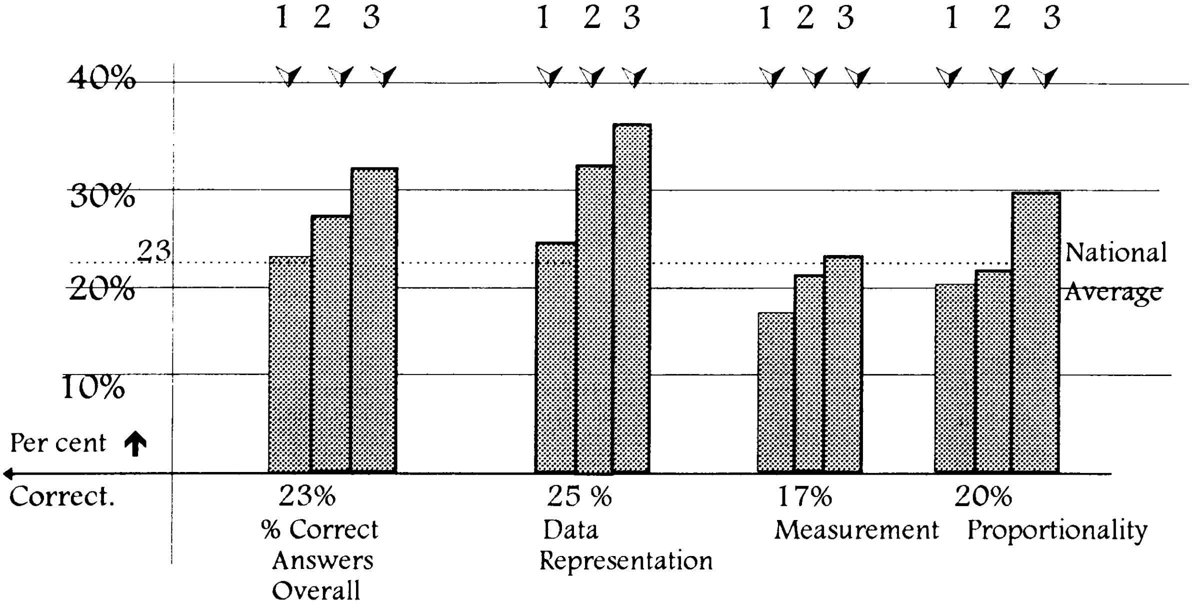
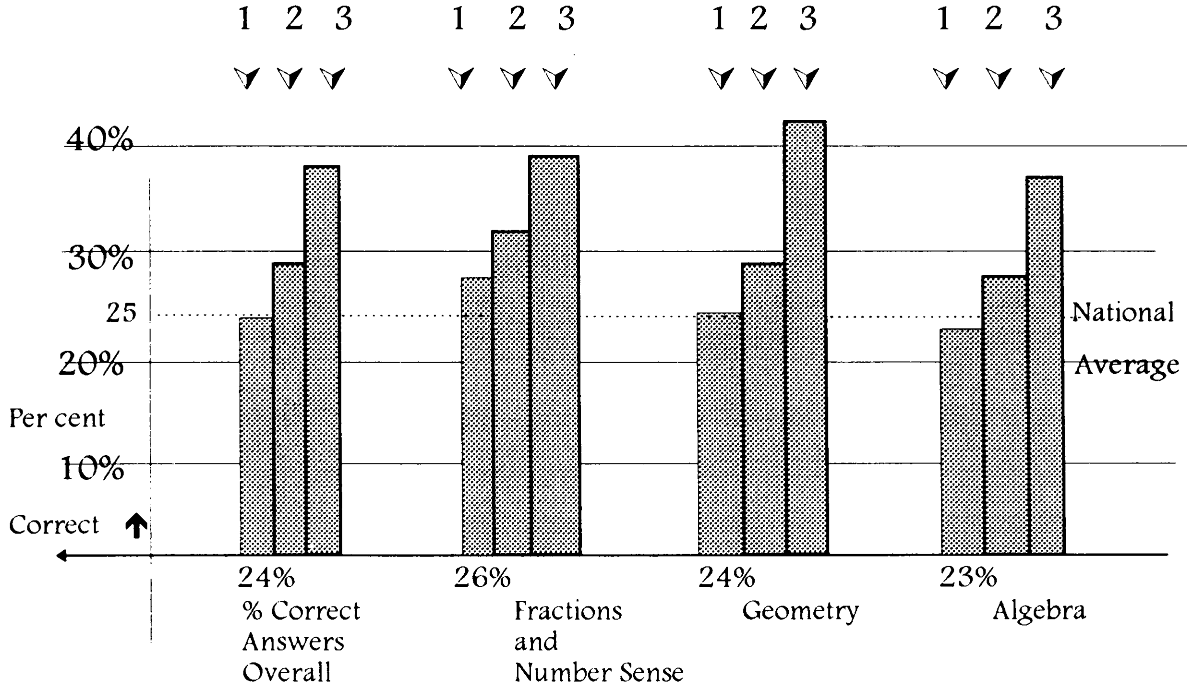
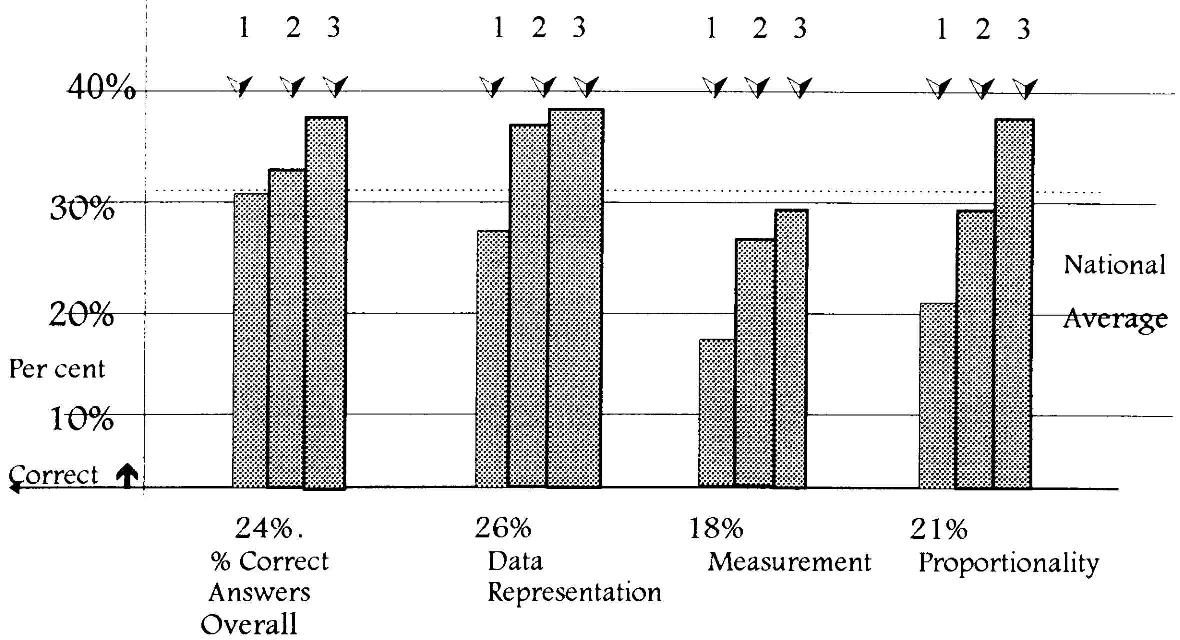


Table 5.10 Standard 6 Mathematics performance



KEY 1 = South Africa 2 = Colombia 3 = Iran

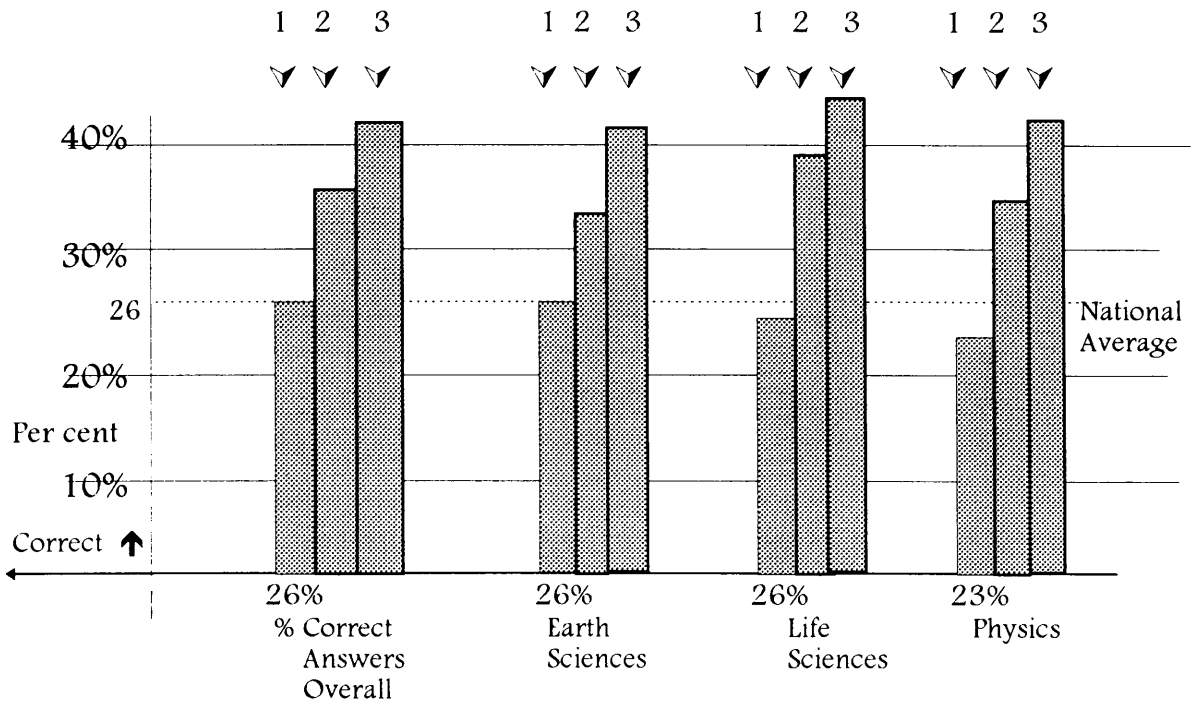
Table 5.10 Standard 6 Mathematics performance **(continued)**



KEY 1 = South Africa 2 = Colombia 3 = Iran

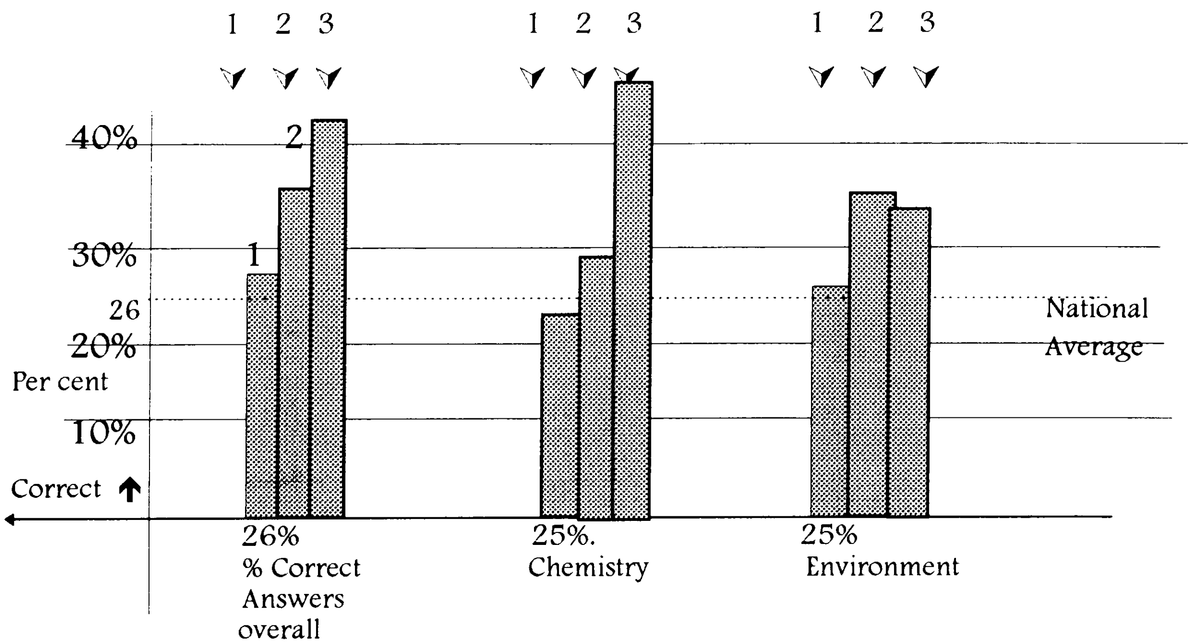
5.5.4 PERFORMANCE BY SUBJECT FIELD - SCIENCE

Table 5.11 Standard 5 Science performance



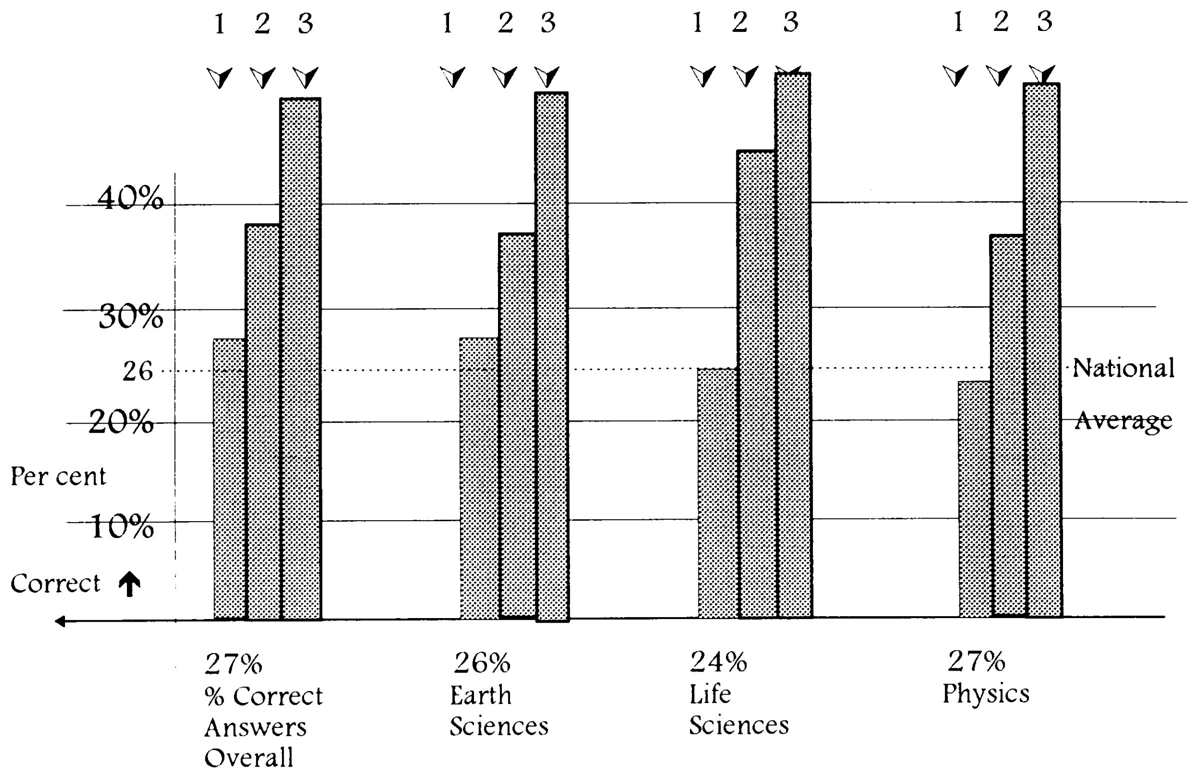
KEY 1 = South Africa 2 = Colombia 3 = Iran

Table 5.11 Standard 5 Science performance (continued)



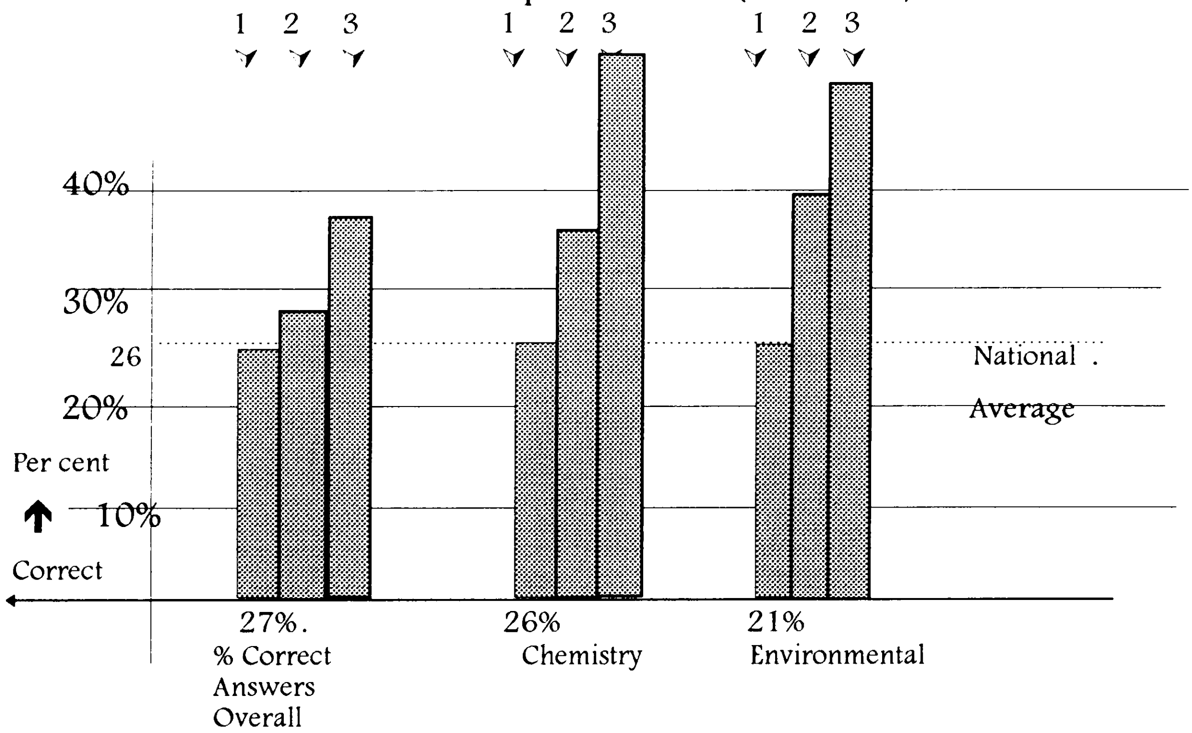
KEY 1 = South Africa 2 = Colombia 3 = Iran

Table 5.12 Standard 6 Science performance



KEY 1 = South Africa 2 = Colombia 3 = Iran

Table 5.12 Standard 6 Science performance (continued)



KEY 1 = South Africa 2 = Colombia 3 = Iran

The countries Iran and Colombia have been shown so as to graphically illustrate the relative achievement of other developing countries compared to South Africa. The percentage of correct answers is indicated in figures on the horizontal axis of all the graphs above only for South Africa.

5.6 MATHEMATICS - ANALYSIS AND COMPARISON OF PERFORMANCE IN SIMILAR AND RELATED QUESTIONS

The questions examined in the sections below have been selected from the fields of Mathematics as described by TIMSS. Within each section, questions have been selected so as to show comparable or anomalous performances in the same field. It must be noted that all questions in clusters A - H have been embargoed by the TIMSS Study Centre and may not be quoted directly. In cases where these embargoed questions are referred to an outline of the question's expectations and format has been stated. The general format of the discussion about questions is set out in the following manner: first question, second question, followed by discussion and commentary. The tables of data that accompany each question in this chapter are set out as follows: each table is divided into three vertical sections, the country, the Lower Grade findings and the Upper Grade findings respectively. The shaded column indicates the correct answer. The percentages in each column indicate the proportion of each national sample of students who chose each possible answer. In the first column the countries being examined are listed - the first row is South Africa and the next three rows are for the participating developing countries and the final four countries were selected as representative of each continent. Each table is headed by an indication of the performance level expected in the question and the degree of curriculum 'fit' with the South African Standard 5 and 6 curricula that were effective in 1995. The data itself has been drawn from the 'p-value' almanacs distributed by the TIMSS Study Centre (TIMSS, 1996 (b-f)). Use has also been made of the South African TIMSS data base. The same format of presentation has been used for the Science questions.

5.6.1 ESTIMATION AND NUMBER SENSE - Questions Q 6 and P 12

QUESTION Q 6

The Smith family uses about 6 000 l of water per week. Approximately how many litres of water do they use per year?

A. 30 000 B. 240 000 C. 300 000

D. 2 400 000 E. 3 000 000

Note: In all the tables that follow in this chapter the percentage of respondents that chose each of the distracters is shown.

PERFORMANCE EXPECTATION : Using routine procedures.

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	15.4	11.7	12.3	20.9	33.4	616	17.9	9.0	10.0	24.6	35.4	509
Iran	10.9	13.4	15.6	30.1	25.9	464	5.4	16.7	21.8	23.8	28.0	463
Colombia	4.5	7.9	14.7	26.4	23.0	335	3.0	6.5	15.6	26.6	25.3	341
Thailand	4.2	7.7	35.5	26.6	24.4	696	2.3	10.0	42.6	23.5	19.4	687
Australia	4.7	6.4	47.4	20.8	18.4	688	6.1	6.1	48.1	17.8	19.9	926
France	6.1	11.0	36.7	32.8	19.4	375	2.4	8.1	47.2	17.6	20.7	370
Canada	3.2	7.6	34.3	30.3	23.7	1 024	3.2	10.4	46.5	19.2	19.7	1 029
Japan	1.7	8.1	38.4	33.1	18.3	646	2.1	5.2	49.9	27.6	14.8	641

QUESTION P 12

Mark's garden has 84 rows of cabbages. There are 57 cabbages in each row. Which of these gives the BEST way to estimate how many cabbages there are altogether?

A. 100 x 50 = 5 000 B. 90 x 60 = 5 400

C. 80 x 60 = 4 800 D. 80 x 50 = 4 000

PERFORMANCE EXPECTATIONS: Using routine procedures

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	18.1	19.4	34.0	21.8		614	21.5	17.9	32.5	21.9		507
Iran	12.8	18.4	37.9	23.0		465	8.8	18.6	45.6	19.9		464
Colombia	9.9	17.8	40.9	16.3		333	7.3	16.3	49.6	13.1		341
Thailand	7.7	9.1	70.3	10.8		696	6.1	9.7	69.9	7.0		687
Australia	4.1	10.2	73.5	10.5		687	3.6	8.7	76.9	9.3		919
France	5.4	16.6	64.9	10.6		371	2.5	13.9	71.5	8.0		370
Canada	5.1	5.6	81.3	7.0		1 030	1.1	9.6	82.5	5.7		1 030
Japan	1.0	6.7	82.8	8.2		646	2.2	7.5	83.5	6.6		641

Both of these questions involve a level of problem solving and an ability to estimate products of two numbers. Question Q 6 requires additional knowledge of the number of weeks in a year. It is notable that the South African Standard 5 group selected more correct answers than the Standard 6 group for both questions. This apparent 'inversion' of achievement levels is a recurring feature in many of the TIMSS questions. The second question received nearly three times as many correct answers as the first. Distracter E in question Q 6 above received the most answers and it would appear that as simple decimal place error has been made in this case in multiplying 6 000 by 50. There appears to be no preferred wrong answer for question P 12 below. The international responses involving distracters D and E suggest strongly that there is an almost universal problem with the correct procedures in multiplication.

5.6.2 ALGEBRA: REPRESENTATION AND VALUES Questions P 15 and P 10

QUESTION P 15 **Which of these expressions is equivalent to y^3**

A. y + y + y   B. y x y x y   C. 3y   D. $y^2 + y$

PERFORMANCE EXPECTATIONS : Knowing

CURRICULUM FIT Standard 5 - No Fit   Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	**19.1**	**17.8**	**47.6**	**9.4**		**613**	**25.6**	**34.3**	**28.0**	**6.1**		**508**
Iran	19.8	36.7	17.0	23.5		465	17.4	53.2	9.7	14.6		464
Colombia	33.1	35.8	9.1	6.6		333	32.9	36.9	7.4	12.5		341
Thailand	36.7	53.1	5.4	3.3		696	23.7	68.1	3.9	2.0		687
Australia	20.0	62.9	9.9	5.1		687	16.8	72.3	6.1	3.5		919
France	45.8	16.7	19.5	12.0		371	22.6	45.8	12.0	16.8		370
Canada	22.5	59.3	10.1	6.1		1 030	17.7	73.4	4.6	2.5		1 030
Japan	11.0	85.9	1.4	0.7		646	9.9	86.5	2.2	1.1		641

QUESTION P 10

If m represents a positive number, which of these is equivalent to m + m + m + m:

A. m + 4   B. 4m   C. m^4 D. 4(m + 1)

PERFORMANCE EXPECTATIONS: Knowing

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	19.2	24.6	39.1	12.2		614	11.2	31.3	46.3	5.9		508
Iran	27.1	30.9	29.9	7.7		465	15.8	33.6	38.8	7.4		464
Colombia	20.0	18.7	47.7	2.6		333	11.1	33.9	43.6	3.6		341
Thailand	10.3	39.9	44.1	4.0		696	7.1	49.1	36.7	5.4		687
Australia	10.6	50.7	34.6	1.9		687	6.7	64.5	24.4	2.8		919
France	7.5	53.3	32.7	2.4		371	5.6	64.8	26.8	1.0		370
Canada	16.1	40.4	36.8	5.0		1 030	7.8	60.7	27.6	2.9		1 030
Japan	7.2	60.5	27.9	3.5		646	7.1	75.3	16.0	1.5		641

Both questions P 15 and P 10 require a knowledge of fundamental mathematical vocabulary and symbols. Question P 15 is virtually the only question in the whole TIMSS battery of one hundred and fifty-one Mathematics questions that South Africa shows a significant increase in achievement between Standard 5 to Standard 6 for the South African respondents (see significance calculation below). The relatively low scores internationally for question P 10, in particular, may indicate a general problem of control and understanding of Mathematics vocabulary and symbols as discussed with reference to 'difference' earlier in 3.2.2.

SIGNIFICANCE

p = 24.6, n = 614

$Sp = \sqrt{\frac{p(1-p)}{n-1}}$

Confidence interval at the 5% level =

Ci = p +/- 1.96 x Sp = 0.973

+/- 1.907

= 22.7 → 25.6

p = 31.3, n = 508

$Sp = \sqrt{\frac{p(1-p)}{n-1}}$

Ci = p +/- 1.96 x Sp = 1.374

+/- 2.693

28.6 → 34.0

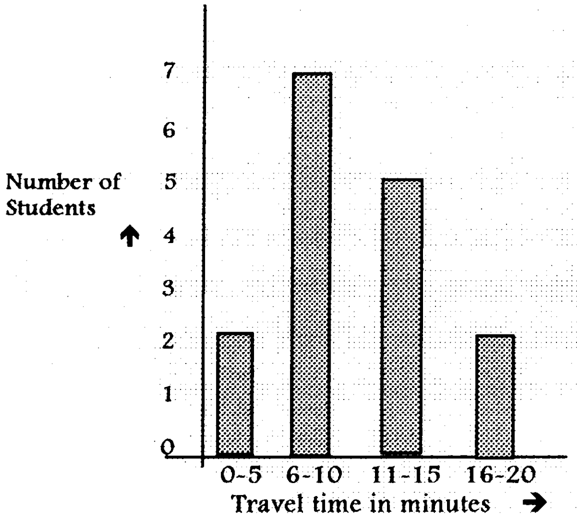
There is no overlap between the confidence fields therefore the difference between the Upper Grade and Lower Grade scores is significant at the 5% level.

5.6.3 DATA REPRESENTATION AND ANALYSIS Questions H 7 and Q 4

QUESTION H 7

The graph shows the time of travel by pupils from home to school. How many pupils travel for more than 10 minutes?

A. 2   B. 5   C. 7   D. 8   E. 15



PERFORMANCE EXPECTATIONS: Using complex procedures

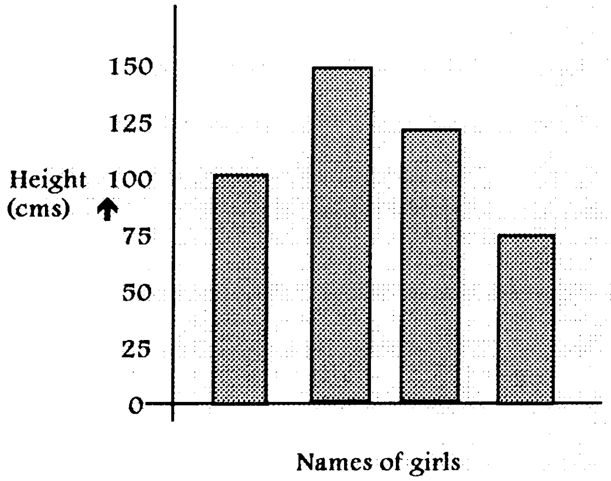
CURRICULUM FIT   Standard 5 - No fit   Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	**10.8**	**17.4**	**21.4**	**9.6**	**37.4**	**1 966**	**12.3**	**17.2**	**21.0**	**8.1**	**38.4**	**1 614**
Iran	21.8	20.2	36.2	6.2	13.6	1 391	15.1	21.3	47.8	5.4	8.6	1 373
Colombia	14.9	15.6	34.6	7.1	17.7	998	11.6	22.5	35.5	7.6	14.8	980
Thailand	5.3	11.4	74.5	2.7	5.4	2 158	2.6	10.7	80.4	2.1	3.7	2 145
Australia	4.8	11.2	72.5	2.9	7.3	2 093	3.2	9.1	80.5	2.1	4.6	2 694
France	7.2	13.0	70.1	2.1	4.9	1 128	5.4	10.0	79.8	1.6	2.2	1 117
Canada	6.6	9.4	72.6	3.2	7.4	3 079	4.7	10.6	73.4	3.6	6.7	3 101
Japan	2.0	8.5	82.3	2.5	4.3	1 952	1.7	8.8	84.2	2.2	3.0	1 961

QUESTION Q 4

The graph shows the heights of four girls. The names are missing from the graph. Debbie is the tallest. Amy is the shortest. Dawn is taller than Sarah. How tall is Sarah?

A. 75cm B. 100cm C. 125cm D. 150cm.



PERFORMANCE EXPECTATIONS : Using complex procedures

CURRICULUM FIT: Standard 5 No fit Standard 6 No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	29.2	34.2	12.8	30.4		616	28.2	28.2	16.0	25.6		493
Iran	11.4	75.2	8.1	4.2		464	8.7	73.0	11.6	5.3		463
Colombia	12.0	50.8	12.5	9.8		335	7.1	62.6	13.2	6.5		341
Thailand	4.8	86.1	8.4	0.6		696	2.3	89.4	7.2	0.5		687
Australia	3.0	88.6	6.1	1.6		688	3.6	87.1	7.3	1.3		926
France	4.1	87.7	5.1	1.2		375	2.2	92.5	3.9	0.3		370
Canada	3.3	86.9	7.5	1.3		1 024	2.3	89.6	6.0	1.4		1 029
Japan	1.5	80.9	15.8	1.3		646	1.0	88.0	9.8	1.3		641

Both of these questions require the same skills and abilities of reading, understanding and extracting and processing data from a histogram. In the latter case, Question Q 4, the expected process is one of elimination rather than adding derived data. The South African candidates performed substantially better on Question Q 4 than on Question H 7. In the international returns H 7 also appears to be the more difficult problem. (Degree of difficulty for H 7 [Lower Grade] 63.8 and [Upper Grade] 69.0 and Q 4 [Lower Grade] 82.3 and [Upper Grade] 84.3.) The distracters A and B for Question H 7 identify pupils who have not carried out the addition (5 + 2). This explains the differences in degree of difficulty .

5.6.4 FRACTIONS AND OPERATIONS - Questions K 9 and L 17

QUESTION K 9

3/4 + 8/3 + 11/8 =

A. 22/15 B. 43/24 C. 91/24 D. 115/24

PERFORMANCE EXPECTATIONS: Problem solving

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	64.3	11.5	5.9	14.3		680	65.6	11.2	6.2	13.0		546
Iran	45.6	10.1	10.8	31.1		465	32.6	10.4	8.5	45.4		463
Colombia	65.1	4.6	3.0	15.5		332	60.0	5.7	5.0	20.0		338
Thailand	40.5	9.0	10.6	38.3		739	37.0	7.0	6.8	47.6		753
Australia	51.2	12.4	5.1	29.7		694	46.3	10.0	5.8	34.7		925
France	58.0	9.6	5.3	23.0		371	22.8	5.9	8.0	60.8		382
Canada	44.5	10.9	4.6	38.7		1 013	40.7	7.7	3.3	46.9		1 056
Japan	5.8	6.3	4.7	82.7		654	5.0	3.8	3.1	87.4		646

QUESTION L 17

What is the value of 2/3 - 1/4 - 1/12 ?

A. 1/6 B. 1/3 C. 83/8 D. 5/12 E. 1/2

PERFORMANCE EXPECTATIONS: Problem solving

CURRICULUM FIT Standard 5 - Fit. Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	9.9	16.0	12.7	39.7	16.9	675	10.2	16.9	13.7	40.5	15.7	568
Colombia	10.7	15.1	15.0	33.9	5.8	330	6.0	21.9	12.6	29.7	7.0	328
Thailand	10.6	47.7	8.2	21.0	8.2	725	8.4	52.4	7.2	20.1	6.5	738
Iran	11.6	17.1	11.2	42.1	9.2	455	11.0	27.3	8.8	37.6	8.6	460
Australia	12.4	38.5	13.8	23.1	7.7	696	8.8	48.8	12.7	20.6	6.0	902
France	12.5	37.0	12.1	23.4	6.2	365	4.6	67.2	5.7	15.8	5.3	385
Canada	9.7	43.4	10.9	26.5	6.4	1 022	8.4	56.0	12.1	17.9	4.8	1 046
Japan	3.9	72.8	4.4	14.3	4.4	654	3.9	79.8	3.2	10.1	2.7	654

As far as Question K 9 is concerned, with the exception of Japan (shown), Belgium (Fl), Hungary and the other oriental countries with outstanding performances, every participating country showed a distracter 'A' bias. To arrive at distracter 'A' for an answer suggests that the students have not learned that to add fractions the Lowest Common Multiple of the denominators must be found. These students all added the denominators. This preference for the distracter 'A' is revealed in both the Lower TIMSS Grade and in the Upper Grade. In South Africa's case, fewer students selected the correct answer and the predilection towards distracter 'A' is still very noticeable. This would appear to indicate that an incomplete mechanical approach has been adopted. As pointed out in 2.1.5.1, this is an example of the problem being fractionated before the whole problem has been examined.

In a similar question (L17) requiring comparable skills to question K 9 there is a marked preference towards distracter D. This preference appears to indicate that a large proportion of the students completed the first part of the subtraction correctly (2/3 - 1/4) and failed to continue with the (-1/12) part of the question. The only exceptions to this trend were again the Oriental countries and Belgium (Fl).

5.6.5 FRACTIONS AND VALUE - Questions M 4 and D 9

Question D 9 (an embargoed question and therefore only the data is presented) and Question M4 below make an interesting comparison in that in D 9 the students are required to identify the smallest fraction and in M 4 they are asked to identify the largest fraction. Whilst conceding the fact that the denominators may have been easier to manage in Question D 4, the substantial difference between the international average for this question (63.2% correct) and Question M 4 below is worth noting.

QUESTION M 4

Which number is the largest?

A. 4/5 B. 3/4 C. 5/8 D. 7/10

PERFORMANCE EXPECTATIONS: Using routine procedures

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	9.3	32.0	5.3	47.4		644	6.2	30.3	4.4	56.6		565
Iran	7.6	21.8	2.9	66.1		468	9.9	25.5	1.6	61.7		458
Colombia	5.9	11.1	2.1	78.2		332	7.3	8.4	2.9	76.8		330
Thailand	31.0	32.6	5.3	29.2		734	33.6	36.1	5.7	23.6		728
Australia	37.6	32.9	3.6	25.1		715	42.9	35.7	3.2	17.9		888
France	37.3	26.6	5.7	27.3		378	50.3	24.4	7.6	16.6		372
Canada	48.0	24.0	3.1	24.0		1 016	56.8	24.0	2.1	16.1		1 048
Japan	57.4	26.0	5.4	10.4		652	59.7	23.9	5.4	11.0		646

QUESTION D 9 This question is embargoed

PERFORMANCE EXPECTATIONS: Using routine procedures

CURRICULUM FIT Standard 5 Fit Standard 6 Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	32.8	8.0	10.7	45.9		2 011	28.9	7.9	10.8	50.3		1 642
Iran	37.8	8.4	1.2	51.3		1 393	48.4	7.3	0.9	42.5		1 382
Colombia	12.0	6.2	2.4	73.6		990	12.2	9.8	1.6	69.5		996
Thailand	52.3	19.1	2.0	26.3		2 194	63.7	15.8	1.8	18.1		2 222
Australia	73.9	7.0	8.8	9.8		2 089	78.6	6.0	7.1	7.6		2 716
France	63.0	10.1	3.9	13.9		1 109	74.0	6.9	5.1	13.4		1 137
Canada	72.6	6.3	6.5	14.0		3 084	79.5	5.3	4.6	9.9		3 117
Japan	88.3	3.1	1.0	7.3		1 943	90.2	2.5	0.7	6.5		1 947

With the international average correct answers being 39.4, Question M4 proved to be one of the more difficult ones. Large numbers of students were not able to identify or calculate that 4/5 is greater than 7/10. This recalls the discussion in 2.1.1 on the complexity of fractions in terms of concept formation.

The differences in the results obtained from these two questions are very interesting in that they show a very poor achievement level for Question M4. For both questions more than half of the Standard 6 group selected the wrong answer. In both cases the Standard 5 group performed significantly better than the senior class.

5.6.6 UNITS AND MEASUREMENT - Questions Q 3 and D 11

Questions D 11 and Q 3 are comparable in that they both refer to units of measurement. D 11 requires the student to select the most suitable unit from those offered to use when weighing a small object.

QUESTION Q 3

Which of these is the longest time?

A. 15 000 seconds B. 1 500 Minutes C. 10 hours D. 1 day

PERFORMANCE EXPECTATIONS: Using complex procedures.

CURRICULUM FIT Standard 5 - Fit. Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	17.7	11.0	19.2	47.1		616	15.7	12.0	13.5	55.9		510
Iran	10.6	20.7	3.4	64.1		465	15.4	30.8	6.3	45.8		464
Colombia	12.8	19.4	7.2	46.8		335	18.7	19.0	6.2	44.3		341
Thailand	8.1	40.0	3.0	48.2		696	8.8	43.5	2.2	44.7		687
Australia	7.3	29.2	4.1	57.3		688	6.3	35.7	2.4	53.8		926
France	11.2	32.7	2.1	52.3		375	5.4	42.6	2.6	46.6		370
Canada	7.5	30.6	2.1	57.8		1 024	6.1	40.9	2.0	49.4		1 029
Japan	5.8	54.9	1.2	37.6		646	4.6	62.3	1.3	31.2		641

QUESTION D 11: This question is embargoed.

PERFORMANCE EXPECTATIONS: Solving a problem

CURRICULUM FIT: Standard 5 Fit Standard 6 Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	15.2	13.4	44.6	22.8		2 011	13.6	9.1	51.1	23.0		1 643
Iran	4.7	7.1	71.8	15.9		1 393	1.5	4.4	78.2	13.4		1 382
Colombia	9.1	6.1	60.5	14.6		990	6.3	6.6	65.5	12.5		996
Thailand	0.9	5.7	78.1	14.5		2 194	0.8	6.2	82.7	14.1		2 222
Australia	1.8	2.7	88.1	6.4		2 089	1.4	2.0	89.8	5.8		2 716
France	5.2	4.9	83.7	5.2		1 109	2.5	3.1	90.6	2.8		1 137
Canada	4.6	4.6	79.6	9.4		3 084	3.3	3.4	81.7	9.8		3 117
Japan	0.8	0.4	96.3	2.1		1 943	0.7	0.7	97.5	0.9		1 947

In the responses to Question Q 3 it is noticeable that in both the high achieving countries and in the countries with lesser achievement records an appreciable proportion of the respondents selected distracter D (1 day) as their answer. It can be speculated that the students either did not complete the multiplication process or have little idea of the relative length of time units. Only four countries scored more than 50% correct for this question. Replies to question D 11, indicate a strongly developed awareness of appropriate units for expressing a particular mass.

The international difficulty for D 11 was 82.9% correct answers, one of the easier questions overall and yet the South African candidates at the Standard 6 level scored just over half correct. South African students however appear to lack an awareness of mass or that there is a discrepancy between curriculum content and maturation level as discussed in 2.1.4.4.

5.6.7 DECIMAL FRACTIONS - Questions J 14 and R 6

QUESTION J 14

Divide: $0.004 \overline{)\,24.56}$

A. 0.614 B. 6.14 C. 61.4 D. 6 14 E. 6140

PERFORMANCE EXPECTATIONS: Using complex procedures

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	26.2	18.0	13.7	10.2	26.0	695	30.7	19.0	14.7	9.1	20.1	563
Iran	20.9	23.1	21.9	10.3	20.4	470	26.7	29.6	14.4	10.1	16.7	373
Colombia	32.9	14.5	8.9	10.8	17.9	329	31.1	18.5	8.7	11.5	13.1	328
Thailand	22.7	25.4	8.9	12.4	28.5	748	23.2	22.5	7.6	10.6	33.7	766
Australia	28.0	27.9	10.8	9.6	20.1	700	26.5	21.6	12.7	119	23.2	898
France	12.6	9.8	7.3	11.4	50.8	362	8.8	6.5	5.2	6.9	70.0	381
Canada	19.4	20.1	8.6	11.7	38.8	1 033	12.5	14.6	12.0	12.0	47.5	1 049
Japan	4.9	11.6	5.4	15.1	62.4	642	3.3	9.3	4.7	11.6	71.1	648

QUESTION R 6

* Subtract 2.201 - 0.753 =

A. 1.448 B. 1.458 C. 1.548 D. 1.558

PERFORMANCE EXPECTATIONS: Using complex procedures

CURRICULUM FIT: Standard 5 - Fit Standard 6 - Fit

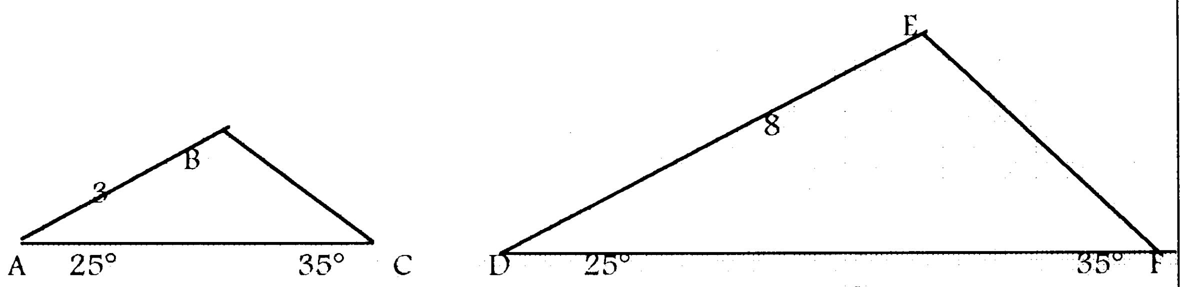
	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	52.2	16.3	15.0	13.3		615	44.8	15.9	19.1	16.9		491
Iran	59.8	13.1	15.2	10.8		465	63.1	15.5	13.9	7.1		464
Colombia	55.3	13.8	15.5	8.9		333	55.6	9.3	21.1	9.5		341
Thailand	86.3	5.6	6.9	0.8		696	86.0	5.3	6.9	1.3		687
Australia	65.8	12.1	14.7	6.6		687	67.6	10.3	11.9	9.5		919
France	82.4	3.0	7.4	6.4		371	87.9	2.3	6.0	3.8		370
Canada	79.4	7.8	8.1	3.9		1 030	81.1	4.9	7.6	5.2		1 030
Japan	80.1	6.2	10.5	2.7		646	84.4	4.5	8.4	2.6		641

Whilst accepting the fact that division of decimals is a more advanced concept than decimal subtraction, the differences, internationally and locally between the Difficulty Indices for these two questions is fairly substantial. (J 14 = 37.7 [LG] and 44.5 [UG], and R 6 = 74.1 [LG] and 75.1 [UG]). For both questions and at both levels the South African scores reveal that an understanding of the meaning of the position of the decimal point may be lacking. Subtraction sums involving decimals may not be as simple as they may appear for middle school students.

5.6.8 CONGRUENCE AND SIMILARITY - Questions P 9 and J 15

QUESTION P 9

Triangles ABC and DEF are similar triangles. What is the length of AC?



A. 2 B. 4 C. 4.5 D. 5.5 E. 32

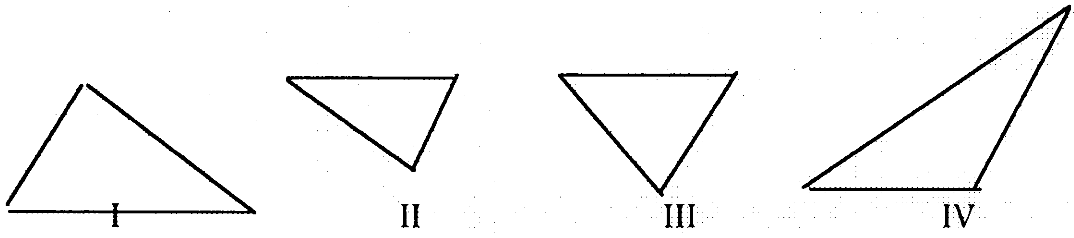
PERFORMANCE EXPECTATIONS: Using complex procedures.

CURRICULUM FIT Standard 5 - No Fit Standard 6 - No Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	10.7	14.5	22.1	27.0	19.9	614	10.8	11.8	23.2	29.1	19.3	508
Iran	4.5	32.1	24.6	27.8	7.1	465	6.9	41.8	17.9	18.1	9.1	464
Colombia	5.3	13.0	20.9	34.8	13.3	333	4.7	14.2	17.8	39.9	6.8	341
Thailand	6.0	24.7	34.1	29.7	3.2	696	3.1	22.2	39.6	28.9	4.0	687
Australia	4.9	23.5	31.7	31.3	5.0	687	3.9	28.1	34.5	27.0	3.9	919
France	3.7	20.4	57.8	13.0	1.0	371	4.0	15.0	58.1	19.5	0.9	370
Canada	2.8	28.6	32.5	30.5	4.2	1 030	2.9	26.7	37.4	27.2	4.6	1 030
Japan	2.1	25.1	53.5	17.6	1.1	646	1.0	15.0	71.4	11.1	0.9	641

QUESTION J 15

Which two triangles are similar?



A. I and II. B. I and IV. C. II and III. D. II and IV. E. III and IV.

PERFORMANCE EXPECTATIONS: Knowing

CURRICULUM FIT STANDARD 5 - No fit STANDARD 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	21.1	23.8	30.3	10.8	6.6	693	24.6	22.4	29.7	10.5	5.5	562
Iran	47.3	35.7	7.0	7.3	1.5	470	69.8	15.7	7.1	5.2	1.4	473
Colombia	34.1	32.0	11.5	9.0	4.5	329	41.7	29.6	11.7	3.8	2.3	328
Thailand	83.6	11.0	1.9	2.9	0.3	748	90.5	4.6	1.7	2.4	0.0	766
Australia	65.6	18.5	6.7	7.4	0.5	700	73.5	15.1	5.9	4.5	0.0	898
France	74.7	6.9	3.6	11.2	1.0	362	81.3	4.6	6.2	6.3	0.6	381
Canada	65.5	22.7	6.7	4.5	0.1	1 033	72.1	14.3	7.0	5.0	0.1	1 049
Japan	85.0	8.0	2.0	3.3	0.7	642	92.9	4.5	1.2	1.4	0.0	648

Questions P 9 and J 15 are based on Similar Triangles. J 15 requires a simple recognition of similar triangles whilst P 9 requires a straight forward ratio calculation based on the concept of similar triangles. The results of both these questions only show a small increase in correct answers between the Standard 5 and the Standard 6 results despite the fact that the Standard 6 students should have been taught this aspect of Geometry and would have been expected to perform substantially better than the Standard 5 classes. With the exception of Thailand, few countries performed well on these two questions. P 9 showed an overall high degree of difficulty, the highest scores being registered by Belgium (Fr), France and Japan at the 58% correct level for the Lower Grade; and only Japan and Belgium (Fr) were able to exceed 60% for the Upper Grade. Question J 15, which required the identification of Similar Triangles, proved to be much easier. The item difficulty for J 15 is nearly twice that of Question P 9. Congruence and similarity in geometry requires appreciable concept formations. Within this field of geometry, following Bloom's Taxonomy, knowledge [knowing] represents a lower level of learning outcomes in the cognitive domain than the ability to apply learned material.

5.6.9 THE HIGHEST AND LOWEST SCORING MATHEMATICS QUESTIONS IN TERMS OF SOUTH AFRICAN PERFORMANCE

It is of some interest to examine the best and poorest questions in terms of South African performance and compare these finding with the international difficulty indices. In terms of instructional objectives, these findings may have been predictable as subtraction, for example, requires only knowledge of relatively simple principles and procedures. What is surprising is the low level of achievement in South Africa, even in the best scoring questions. The highest scoring questions for the Lower Grade (Standard 5) are R 12 and R 6 which involve subtraction of whole numbers and subtraction of decimal fractions respectively. In the case of the Upper Grade (Standard 6) the highest scoring questions are R 12, which required students to subtract two decimal fractions, and L 10 which requires students to select the highest temperature from a day/time temperature chart. It would appear from this data that fractions require more advanced concepts and procedures, as already discussed in 2.1.1. In the case of the lowest scoring questions, the Lower Grade showed very low performances in questions involving the recognition of patterns (R 10) and in the value of fractions (M 4). For the Upper Grade Questions M4, requiring the identification of the largest fraction from a selection of four, and K6 requiring an approximation from data supplied, were the lowest scoring items. It would appear that the results of Question M 4 particularly, indicates a widespread national problem in teaching of fractions.

5.6.9.1 Mathematics - the highest scoring questions - Lower Grade - Questions R 12 and R 6

QUESTION R 12

Subtract: 6 000
-2 369

A. 4 369 B. 3 642 C. 3 631 D. 3 531

South African results:

A. 29.8 B. 7.0 C. 53.3 D. 6.2 (per cent response)

International Index of Difficulty 86.3

QUESTION R 6

Subtract: 2.201 - 0.753 =

A. 1.448 B. 1.458 C. 1.548 D. 1.558

South African results

A. 52.2 B. 16.3 C. 15.0 D. 13.3 (per cent response)

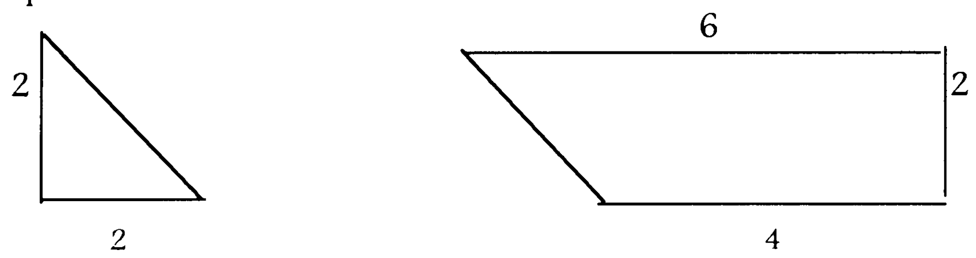
International Index of Difficulty 74.1

Question R 12 appears as one of the better questions for South Africa at both the Upper Grade and at the Lower Grade. It is enlightening to note that the Lower Grade out-scored the Upper Grade in this question. Questions R 6 and R 12 are both direct subtractions, the former of decimal fractions and the latter, of whole numbers. In both questions only just over half of the South African sample were able to obtain the correct answer.

5.6.9.2 Mathematics - the lowest scoring questions - Lower Grade - Questions R 10 and M 4

QUESTION R 10

How many triangles of the shape and size of the small triangle can the trapezoid shown be divided into?



A. Three B. Four C. Five D. Six

South African results

A. 48.6 B. 24.1 **C. 8.6** D. 15.9 (per cent responses)

International Index of Difficulty 47.8

QUESTION M 4

Which number is the largest?

A. 4/5 B. 3/4 C. 5/8 D. 7/10

South African results:

A. 9.3 B. 32.0 C. 5.3 D. 47.4 (per cent responses)

International Index of Difficulty 36.1

Question R 10 involved pattern recognition which demands some maturation of perception. Internationally, this question was slightly above average in difficulty. Question M 4 would appear to be a fairly straight forward recognition of number values which proved to be a difficult question for South African students and internationally.

5.6.9.3 Mathematics - the highest scoring questions - Upper Grade - Questions R 12 and L 10

QUESTION R 12

Subtract: 6 000
-2 369

A. 4 369 B. 3 642 C. 3 631 D. 3 531

South African results:

A. 34.3 B. 6.3 **C. 51.8** D. 4.5 (per cent response)

International Index of Difficulty 86.3

Question R 12 was one of the highest scoring question for both the Lower and Upper Grades.

QUESTION L 10

The chart shows temperature readings made at different times on four days.

	6 a.m	9 a.m	Noon	3 p.m.	8 p.m.
Monday	15	17	20	21	19
Tuesday	15	15	15	10	9
Wednesday	8	10	14	13	15
Thursday	8	11	14	17	20

When was the highest temperature recorded.

A. Noon on Monday B. 3 p.m. on Monday C. Noon on Tuesday
D. 3 p.m. on Wednesday

South African results:

A. 21.1 **B. 49.2** C. 16.2 D. 11.1 (per cent response)

International Index of Difficulty = 87.7

Question R 12, involving subtraction of whole numbers, should lie within the skills taught in Standard 3 or Standard 4. South African students scored less that two thirds of the international achievement for this question. Question L 10 required the students to locate the largest number (the highest temperature) on the chart. They then had to locate this number. Internationally, this question was relatively well handled. The South African scores were just over half the International achievements at 49.2 per cent of students with the correct answer.

5.6.9.4 Mathematics - the lowest scoring questions - Upper Grade - Questions M 4 and K 6

QUESTION M 4				
Which number is the largest?				
A. 4/5	B. 3/4	C. 5/8	D. 7/10	
South African results:				
A. 6.2	B. 30.3	C. 4.4	D. 56.6	(per cent responses)
International Index of Difficulty 36.1				

As pointed out above the observed data for this question are that M 4 is the most difficult question for both Standards 5 and 6 but the Upper Grade did not perform as well as the Lower Grade. There are no apparent reasons for this achievement inversion.

QUESTION K 6					
Last year there were 1 172 students enroled at Beaton High School. This year there are 15 per cent more students than last year. Approximately how many students are at Beaton High School this year?					
A. 1 800	B. 1 600	C. 1 500	D. 1 400	E. 1200	
South African results:					
A. 32.8	B. 8.1	C. 20.0	**D. 11.4**	E. 24.5	(per cent responses)
International Index of difficulty 44.1					

5.6.10 MATHEMATICS FREE RESPONSE ITEMS

Approximately one quarter of the TIMSS Mathematics questions were Free Response Items and, without exception, the South African performance in these questions was almost non-contributory to the final scores with the lowest score being 0.2 per cent correct answers. In the majority of cases the coders recorded in excess of 90 per cent for indecipherable or no answer codes. The FRI for which South Africa scored the highest score was 5.9 per cent of the sample gaining a mark. At a speculative level, if the South African students had scored on a par with the scores for the multiple choice items the South African position would have been in the region of 370 to 380 on the ranking tables. Cursory examination of the returns from the students' questionnaires, which will be discussed more fully in Chapter 6, suggests that the students could not or would not construct answers for themselves. Whilst language problems and a poor ability to express themselves in a second language may once again have been a contributory factor, the student questionnaires (discussed in Chapter 6) indicates that just over 22 per cent of the students were answering the TIMSS test papers in a language they used always or frequently at home. These students should not have experienced self-expression problems. This unwillingness or apathy may be a reflection of the socio-political climate, discussed in Chapter 4 in the majority of South African schools at the end of 1995.

5.6.11 AN OVERVIEW OF THE MATHEMATICS SECTIONS OF TIMSS

The overall TIMSS findings reveal a very low level of development in terms of the vocabulary and symbolism of Mathematics. As indicated already in the commentary on the questions, above, adequate concept formation has not taken place; and poor problem solving skills characterize the questions demanding the ability to integrate learning with problem solving. Bell (1978: 311) notes that:

> Problem solving is an appropriate and important activity in school Mathematics because the learning objectives which are met by solving problems and learning general problem solving procedures are of significant importance ....

The best scoring questions showed correct answers only in the order of 50 per cent. Even the most elementary of processes such as addition, subtraction and the awareness of the magnitude and value of numbers are handled with uncertainty by the general sample of students.

* * * * *

5.7 SCIENCE - ANALYSIS AND COMPARISON OF PERFORMANCE IN SIMILAR AND RELATED QUESTIONS

The questions examined in the sections below have been selected from the fields of Science as nominated by TIMSS and within each section questions have been selected so as to show comparable or anomalous performances in the same field. It must be noted that all questions in clusters A - H have been embargoed by the TIMSS Study Centre and may not be quoted directly. In cases where these embargoed questions are referred to an outline of the question's expectations and format has been stated.

5.7.1 EARTH SCIENCES

5.7.1.1. Earth Sciences- The Atmosphere - Questions O 12 and F 5

QUESTION O 12

Air is made up of many gases. Which gas is found in the greatest amount?

A. Nitrogen B. Oxygen C. Carbon dioxide D. Hydrogen

PERFORMANCE EXPECTATIONS: Understanding simple information

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	13.7	53.3	18.4	11.2		621	9.8	57.2	17.2	11.7		518
Iran	7.3	73.5	12.8	5.7		459	4.4	78.1	5.5	11.3		448
Colombia	.	.	.	.	.		.	.	.	.		
Thailand	18.6	55.2	22.6	2.7		707	17.6	58.8	17.7	5.1		703
Australia	16.1	57.3	19.7	6.4		694	15.9	52.6	23.0	7.6		893
France	11.2	69.0	16.8	0.9		374	12.8	72.1	11.7	2.4		370
Canada	9.3	60.0	26.7	3.3		1 042	20.7	56.7	18.5	4.0		1 014
Japan	56.8	28.8	12.2	2.0		648	53.3	30.5	12.6	3.4		652

QUESTION F 5

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	40.8	14.4	10.7	30.9		2 013	39.1	14.1	10.6	33.8		1 682
Iran	76.1	4.4	3.3	15.6		1 392	79.9	2.3	4.1	12.6		1 392
Colombia	58.0	9.6	11.7	14.4		992	63.7	9.5	7.3	13.5		989
Thailand	77.3	2.8	6.2	13.4		2 208	82.7	1.9	5.7	9.1		2 232
Australia	86.6	5.2	2.4	5.3		2 117	89.3	4.5	2.2	3.6		2 691
France	64.6	4.8	1.4	26.9		1 111	68.8	3.6	1.5	23.7		1 142
Canada	86.4	5.8	1.6	5.6		3 069	90.8	3.8	1.3	3.7		3 142
Japan	70.0	4.8	1.5	23.2		1 949	76.5	3.3	0.7	19.4		1 946

Question F 5, is an embargoed question, for which only the data is shown above. It enquires into the availability of oxygen at altitude and, because of the overlap of content, it is interesting to compare the results of this question with those of question O12 above. Whilst question F 5 was answered more than adequately by most countries, Question O 12 shows the characteristics of what could be regarded as an internationally held misconcept (see 2.1.4.4 & 2.1.6). It is noticeable, for this question, how many countries opted for oxygen as the most abundant gas in the atmosphere. It would seem that the fundamental misconcept is derived from the pedagogic problem where familiarity equals abundance in many students' minds and this kind of misconcept carries through much of Science Education in the later years at school. Question O 12 is a recall of knowledge question involving information that a large proportion of students appear not to have acquired. This should be taken as an indicator for appropriate teaching technique and a point to stress in class.

Of the recorded results for participating countries, only South Africa failed to show appreciable increase in correct answers from Grade 7 to Grade 8 in their responses to Question F 5. With the exception of Colombia, Grade 7 and

South Africa, both grades, all the national scores were over 60% correct for this latter question.

5.7.1.2 Earth Sciences - Astronomy - Question Q 16

Question Q 16, below, is one of the very few questions in the TIMSS papers involving astronomy. To a large extent the findings suggest that only a minority of students have a concept of how large the universe really is. This is the prior knowledge (see also 2.1.4.2) that should be in the students' possession. These findings also show how little 'general knowledge' has been acquired by the majority of students. Even the high achieving countries scored relatively poorly on this question. The highest score in the Lower Grade was 36% correct achieved by England and 33% by the United States and Belgium (Fl). At the Higher Grade, New Zealand and Norway scored over 40% correct answers.

QUESTION Q 16

How long does it take light from the nearest star other than the sun to reach earth?

A. Less than 1 second B. About 1 hour C. About 1 month
D. About 4 years.

PERFORMANCE EXPECTATIONS: Handling complex data.

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	17.1	31.4	15.8	25.7		553	22.2	30.1	19.3	23.4		483
Iran	44.3	23.1	11.1	13.0		465	42.6	23.1	11.8	17.2		464
Colombia	31.7	16.4	10.5	12.4		335	26.9	12.8	9.2	18.3		341
Thailand	.	.	.	.		.	.	.	.	.		
Australia	34.4	19.3	8.3	35.4		688	30.4	16.9	10.0	40.0		926
France	50.2	18.1	7.3	14.7		375	52.9	16.8	4.9	19.4		370
Canada	37.2	15.6	12.5	32.0		1 024	43.7	14.2	11.5	28.1		1 029
Japan	31.2	19.7	17.4	30.9		646	33.3	14.7	17.5	33.8		641

It is of interest to note that even the high achieving oriental countries scored a relatively low per cent of correct answers to this question. The South African scores were exceptional in that at both Lower and Upper Grades the South African scores were higher than a substantial proportion of participating countries. The Difficulty Index for this question internationally was 23.5 (Lower Grade) and 26.7 (Upper Grade) and at both grade levels South Africa performed relatively well.

5.7.2 ENERGY

5.7.2.1 Energy - Fuels - Questions K 15 and C 12

Energy is one of the important concepts that in the Standard 6 curriculum and it would appear that in the school population as a whole, energy concepts and sources of energy are not being established clearly in the students' minds.

QUESTION K15

Fossil fuels are formed from ...

A. Uranium B. Sea water C. Sand and gravel

D. Dead plants and animals

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT : Standard 5 - No fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	18.1	33.2	19.3	25.6		680	21.3	33.5	20.4	21.0		544
Iran	15.9	7.0	8.4	68.2		465	9.5	7.6	6.0	75.1		463
Colombia	25.6	4.3	15.1	45.8		332	24.5	4.7	10.7	51.3		338
Thailand	39.3	5.8	9.6	43.9		739	30.7	5.7	4.8	57.6		753
Australia	20.7	9.4	14.6	53.5		694	19.6	6.0	11.0	62.2		925
France	19.6	12.6	24.0	36.0		371	12.1	9.0	15.4	61.3		382
Canada	12.4	6.1	13.6	67.4		1 013	11.7	3.4	15.2	69.3		1 056
Japan	32.5	4.9	12.6	49.1		654	32.0	3.0	11.9	53.1		646

QUESTION C 12 This is an embargoed question.

PERFORMANCE EXPECTATIONS: Handling complex information

CURRICULUM FIT Standard 5 No fit Standard 6 No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	9.0	24.3	33.7	33.0		1 958	9.6	24.8	29.9	35.7		1 623
Iran	15.1	6.7	36.3	40.8		1 420	12.2	7.5	41.1	37.3		1 400
Colombia	6.7	6.8	53.5	23.5		996	5.5	3.5	57.6	24.1		977
Thailand	8.3	7.9	49.3	33.7		2 243	8.3	9.3	58.4	23.0		2 241
Australia	3.4	14.5	49.0	32.2		2 072	2.9	11.8	51.6	32.5		2 687
France	6.9	15.0	32.6	38.5		1 131	7.0	14.3	28.2	46.9		1 106
Canada	3.7	8.3	64.2	21.9		3 073	5.3	7.1	63.2	23.2		3 146
Japan	3.8	4.5	63.3	28.1		1 939	4.2	4.6	61.6	29.2		1 973

Question C 12 is a 'reverse format' of Question K 15 in that it asks for a non-fossil fuel to be identified. Question C 12 is on the embargo list. Performance in these two questions is very informative though. From Question K 15 and C 12 it would appear that a large proportion of students are unaware of what fossil fuels are and for the teacher there is the consequent dilemma of how to teach the 'Greenhouse Effect' if students are not aware of the addition of carbon dioxide to the atmosphere from the combustion of fossil fuels.

It is also apparent that between a third and a half of students do not know that wood is not a fossil. Distracter D that more than one third of South African students selected suggests that they have little knowledge of natural gas and its production and use as an energy source in South Africa.

5.7.2.2 Energy - Types - Questions B 2 and D 4

QUESTION B 2 This is an embargoed question

PERFORMANCE EXPECTATIONS: Processing complex information

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	23.9	36.3	14.7	21.1		2 593	25.7	38.0	12.8	20.7		2 151
Iran	20.5	50.2	16.5	11.1		1 868	17.3	62.9	7.8	11.1		1 831
Colombia	29.9	43.9	9.8	11.9		1 321	29.0	43.0	9.4	14.1		1 329
Thailand	22.6	57.4	7.1	12.0		2 907	22.9	60.8	5.2	10.3		2 889
Australia	29.0	51.3	9.6	9.0		2 783	27.3	56.5	7.7	7.8		3 605
France	24.6	56.8	12.6	3.0		1 513	38.4	55.5	11.4	2.7		1 479
Canada	27.5	54.6	13.0	4.4		4 110	23.7	62.9	8.9	4.2		4 144
Japan	31.4	55.3	8.8	4.4		2 590	28.6	62.0	6.5	2.7		2 608

QUESTION D 4

PERFORMANCE EXPECTATIONS: Processing complex information

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	14.2	22.9	23.0	35.2		2 010	14.1	15.7	20.9	45.8		1 639
Iran	8.6	15.8	57.5	14.3		1 393	7.9	12.2	65.7	11.8		1 384
Colombia	11.6	11.5	42.6	26.3		990	13.4	9.3	43.7	24.7		996
Thailand	8.7	5.0	68.1	17.4		2 194	6.9	4.6	71.4	16.5		2 222
Australia	10.6	11.7	61.6	14.0		2 089	9.4	10.8	65.4	13.3		2 716
France	10.3	13.1	42.4	26.9		1 109	6.4	10.5	50.9	26.8		1 137
Canada	11.4	11.7	59.0	16.0		3 084	9.3	14.9	58.3	16.4		3 117
Japan	9.6	8.4	58.3	23.1		1 943	8.7	10.1	60.8	20.1		1 947

Question B 2 is embargoed but deals with the energy produced from combustion. Apart from being a middle of the range question in terms of difficulty (Difficulty Index = 57.9 [UG] and 49.1 [LG] there was a strong predilection of between one fifth and one quarter of the students to select the distracter A, which suggested that the waste energy during combustion was in the form of electricity.

Question D 4 is also embargoed and likewise deals with energy conversions. In the South African context this was one of the relatively few questions which involved an identifiable culture problem. An appreciable number of South African candidates took the option that suggested the energy change proposed took place in a refrigerator. In a country where paraffin refrigerators are not uncommon this might be seen as an acceptable answer. No other country had as many answers selecting this distracter.

5.7.3 HUMAN BIOLOGY

5.7.3.1 Human Biology - The Blood - Questions G 8 and H 1

QUESTION G 8 is an embargoed question that enquires into the functions of the blood.

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	21.4	39.2	11.0	25.9		1 973	24.0	34.4	12.9	26.3		1 649
Iran	21.7	40.0	3.5	32.3		1 470	38.8	28.4	3.3	28.9		1 385
Colombia	28.8	44.8	3.0	18.1		1 005	30.7	44.5	1.9	17.5		991
Thailand	19.7	52.8	9.8	17.1		2 198	15.2	67.7	5.7	11.0		2 185
Australia	21.1	65.0	4.9	7.8		2 111	14.6	76.2	3.3	5.2		2 706
France	22.0	55.8	3.7	15.8		1 135	15.9	65.6	3.3	13.0		1 114
Canada	23.6	58.4	5.8	10.8		3 048	21.4	62.4	4.2	11.6		3 145
Japan	20.6	43.6	9.7	25.6		1 958	5.9	81.4	3.6	8.7		1 947

QUESTION H 1

Which one is not a function of the blood?

A. Digesting food
B. Protecting against disease
C. Carrying waste materials away from the cells.
D. Carrying oxygen to different parts of the body

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		
South Africa	36.8	25.5	17.9	16.4		1 965	35.4	22.7	20.2	18.8		1 620
Iran	47.4	23.0	16.3	12.1		1 381	56.1	16.3	14.4	12.1		1 362
Colombia	55.7	12.8	13.3	10.4		998	64.2	9.9	14.7	6.8		980
Thailand	88.9	4.6	2.4	3.5		2 158	93.3	2.5	1.7	2.0		2 145
Australia	72.3	9.9	9.4	7.3		2 093	78.9	8.8	7.8	4.1		2 694
France	57.1	19.8	13.4	6.8		1 128	66.0	15.2	10.5	7.3		1 117
Canada	73.2	9.8	9.4	7.0		3 079	77.1	10.2	6.5	5.7		3 101
Japan	69.8	11.0	9.8	8.7		1 952	81.5	9.4	4.7	3.9		1 961

Question G 8 is an embargoed question relating to the functions of the blood. Although South African Standard 5 and Standard 6 curricula do not encompass Human Biology, common sense and exposure to AIDS education rather than knowledge should have enabled students to answer this question adequately.

Question H 1 above is a 'reverse question' based, in terms of content, on Question G 8 above. Except for the Oriental high achieving countries, few countries performed well on either of these two questions. In the South African case little over a third of the students selected the correct answer.

5.7.3 HUMAN BIOLOGY

5.7.3.1 Human Biology - Nutrition - Question H 2

QUESTION H 2

What are vitamins?

A. Substances that break down foods

B. Bacteria that people get when they eat some foods

C. Substances that people make from protein

D. Substances that people need in small amounts in order for their bodies to function normally.

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	10.7	23.1	33.9	28.9		1 966	8.6	22.6	37.2	29.0		1 620
Iran	3.1	8.3	6.9	80.9		1 381	0.8	15.2	6.5	76.8		1 362
Colombia	4.9	3.5	10.4	75.8		998	1.5	6.1	8.6	81.6		980
Thailand	2.5	6.1	13.9	77.1		2 158	3.6	4.7	9.2	81.7		2 145
Australia	2.7	2.6	16.3	77.5		2 093	2.8	2.7	11.8	82.4		2 694
France	5.0	15.6	12.2	63.6		1 128	4.2	13.3	10.4	70.0		1 117
Canada	1.6	3.2	22.1	72.5		3 079	2.4	2.7	16.6	77.8		3 101
Japan	4.9	17.0	24.1	53.9		1 952	4.6	13.9	19.0	62.3		1 961

As with Question H 5 discussed towards the end of this chapter, South African students know little of nutrition and/or vitamins. In a country plagued by malnutrition, this level of ignorance may have serious cost implications in terms of human lives and childhood development. The concept held by more South African students than those who selected the correct answers is that vitamins are made from proteins suggests that an alternative concept that is incorrect is widely held. In international terms the difficulty index shows that this was a high scoring question (Difficulty Index (LG) = 75.5 and 79.3 at the Upper Grade.

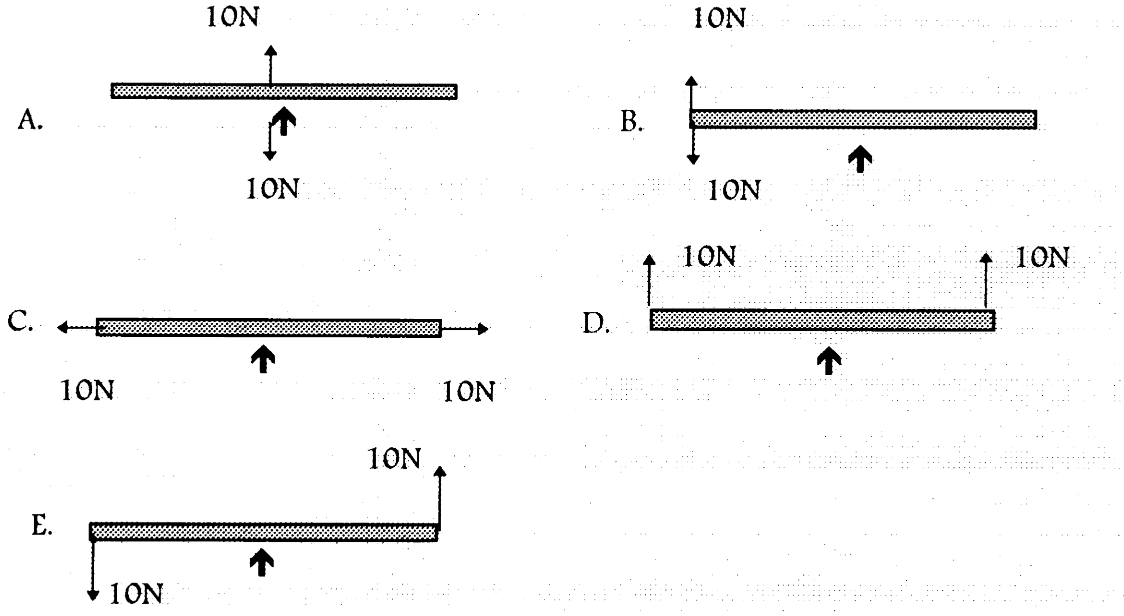
5.7.4 PHYSICS

5.7.4.1 Physics - Levers and Moments - Questions L 1 and I14

Question I 14, dealing with Human Biology, and Question L 1 from the Physics section both involve the concept and application of levers.

QUESTION L 1

A uniform rod is pivoted at its centre. It is acted on by two forces in the same plane. Each force has the same size, equal to 10N (Newton). In which case is there a turning effect?



PERFORMANCE EXPECTATIONS: Understanding complex information

CURRICULUM FIT STANDARD 5 - No fit STANDARD 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	**16.1**	**10.6**	**35.7**	**14.2**	**17.8**	**678**	**14.4**	**11.9**	**38.1**	**12.6**	**18.8**	**548**
Iran	24.3	9.2	31.4	5.5	24.4	445	20.0	11.0	17.0	9.3	37.8	450
Colombia	30.9	8.0	21.5	7.4	25.2	330	27.1	5.4	26.4	7.0	26.5	328
Thailand	41.5	3.6	17.5	4.5	31.6	726	39.3	4.6	18.6	5.0	31.1	738
Australia	18.9	7.1	15.8	5.8	48.2	696	15.7	8.4	12.9	5.1	55.1	902
France	23.4	5.8	11.6	6.0	43.6	365	23.1	6.3	9.7	5.6	50.9	385
Canada	22.8	8.2	16.4	5.8	45.5	1 022	15.7	7.1	13.6	8.7	53.1	1 046
Japan	9.2	4.9	9.1	5.7	70.2	654	6.6	4.0	6.7	4.5	78.1	654

QUESTION I 14

When you bend your arm at the elbow, the bones and muscles in your arm are acting as a system. What simple machine does this system represent?

A. Inclined plane B. Pulley C. Wedge D. Lever.

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	19.8	22.0	23.7	29.0		697	22.3	22.0	22.7	28.4		564
Iran	18.8	22.1	10.5	45.3		475	22.7	14.5	14.3	45.9		463
Colombia	24.4	15.3	7.3	46.3		325	18.4	12.9	7.5	51.2		328
Thailand	21.4	38.2	12.5	26.2		770	17.3	43.7	10.7	26.8		771
Australia	7.4	27.4	9.3	54.3		680	5.0	25.9	8.2	58.0		894
France	11.8	19.1	6.5	55.2		380	12.4	12.0	5.7	66.6		364
Canada	8.4	22.0	9.3	59.4		1 033	8.3	22.2	9.5	59.5		1 053
Japan	4.4	22.9	21.9	50.2		645	1.2	25.1	22.4	50.5		669

There appears to be a substantial proportion of the students of all nations who are not able to identify the properties of levers. In Question, L 1, there was a significant proportion of students from most nations who could not interpret the zero turning effect of equal and directly opposed forces correctly (the tug-of-war situation). Only the Oriental nations, such as Japan and Korea, performed well in this question. All three of the other developing countries tended to make the same error at both grade levels. With the exception of South Africa though, distracter A also received a substantial number of answers. It can be speculated that the technical notation and symbolism of levers, such as the arrow for a force and the symbol for a fulcrum, is not widely understood.

In Question I 14, there was a consistently high proportion (one fifth or more) of students from most nations who regarded the elbow as a pulley system which a failure to understand mechanical systems or the function of muscles and joints.

5.7.4.2 Physics - Light - Questions C 9 and M 14.

QUESTION C 9 This is an embargoed question.

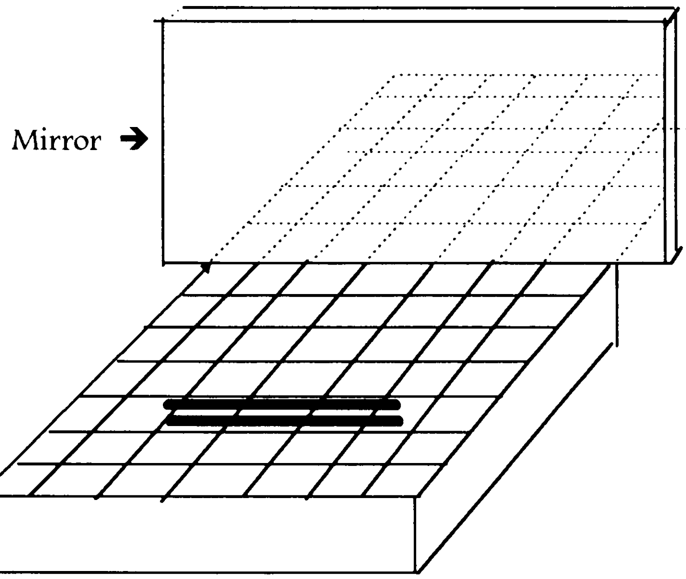
PERFORMANCE EXPECTATIONS: Problem solving

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	10.8	26.8	22.7	35.8		2 040	10.7	25.7	22.3	37.5		1 676
Iran	8.2	61.8	10.4	18.3		1 420	8.2	66.7	6.5	17.5		1 400
Colombia	10.3	48.4	7.8	25.6		996	7.0	48.9	12.5	24.6		977
Thailand	9.8	55.8	7.8	26.3		2 243	8.7	58.2	7.0	25.5		2 241
Australia	4.7	72.8	5.2	16.6		2 072	4.8	75.8	4.8	14.3		2 687
France	1.6	88.8	1.4	7.3		1 131	1.6	83.2	2.3	11.8		1 106
Canada	4.0	75.6	3.7	16.0		3 073	4.2	76.0	4.3	14.9		3 146
Japan	4.9	81.3	2.1	11.7		1 939	4.2	78.1	2.9	14.6		1 973

QUESTION M 14

The picture shows a pencil that is lying on a shelf in front of a mirror. Draw a picture of the pencil as you would see it in the mirror. Use the pattern of lines on the shelf to help you.



PERFORMANCE EXPECTATIONS: Processing complex data

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	10	11	12	70	71	72	73	79	90	99		N
South Africa	2.0	0.1	0.3	0.4	0.2	1.3	0.2	2.9	0.4	92.3		405
Iran	46.1	0.2	5.6	4.6	1.8	19.9	0.8	4.7	3.1	13.2		468
Colombia	45.2	-	1.9	3.6	0.9	29.4	1.8	8.1	-	9.0		332
Thailand	57.6	0.3	5.9	8.5	0.4	11.5	0.3	10.1	0.1	5.4		734
Australia	67.6	0.3	0.5	7.7	0.6	16.5	0.3	1.7	0.3	4.4		715
France	73.1	-	1.7	11.1	1.8	4.6	0.3	0.8	0.2	6.5		378
Canada	68.5	0.1	1.2	8.2	1.2	14.5	1.2	2.6	0.5	2.1		1 016
Japan	80.7	0.5	-	8.6	0.8	3.7	0.8	2.5	0.7	1.7		652

Note: EXPLANATION OF THE CODES 10, 11 and 12 are correct answers. 70, 71 and 72 are incorrect answers. 90 and 99 indicates a question either not answered or the answer was indecipherable.

Question C9 deals with the position of a reflected image in a mirror. Apart from the rather poor South African showing on this question, the international scores were high and few countries scored below 70% (UG and LG). The main South African problem appears to be a lack of understanding that the object's distance in front of the mirror is equal to the image's distance behind the mirror which is fundamental to the understanding of reflection. I should be pointed out though, that reflection of light and mirror images were not a part of the curriculum effective at the time of the TIMSS testing in 1995.

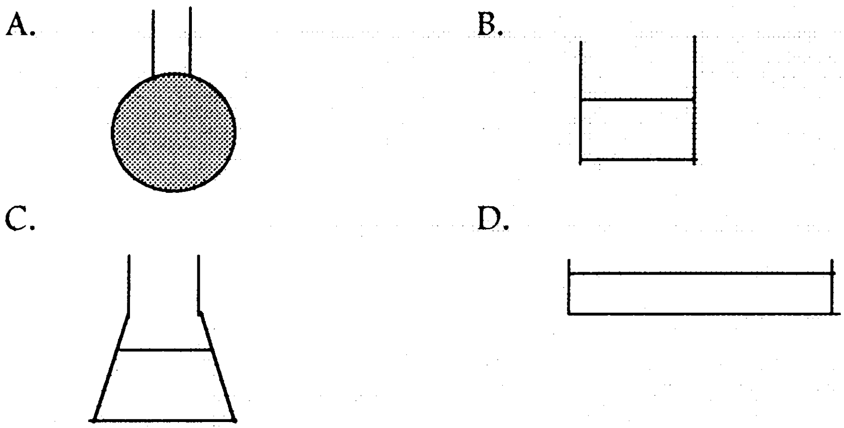
Question M14, the data for which is tabulated above, is a Free Response item dealing with the same subject matter of reflection and mirror images as Question C 9 discussed above. There were however fewer clues provided for the student to draw upon in constructing an answer. Only 2.3% of South African students obtained a mark for Question M 14 which is particularly disappointing when compared to the South African results for Question C 9 discussed earlier.

This example has been included for discussion to make the point that in ALL the Free Response Items the South African students, as already noted, either could not or would not construct an answer for themselves. The highest scoring of all the Free Response Items shows South Africa scoring only 5.9% correct responses.

5.7.4.3 Physics - Evaporation - Questions K 14 and N 3

QUESTION K 14

A student put 100ml of water in each of these open containers, and let them stand in the sun for one day. Which container probably lost the most water due to evaporation?



PERFORMANCE EXPECTATIONS: Processing complex data

CURRICULUM FIT Standard 5 - No fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	9.6	18.2	7.1	41.3		675	11.2	16.8	8.4	43.4		537
Iran	13.5	2.4	1.6	74.6		465	11.2	1.8	3.9	76.4		463
Colombia	27.9	2.4	2.9	49.2		332	26.1	2.5	2.9	59.0		338
Thailand	7.9	2.8	2.4	84.0		739	4.5	2.7	1.1	90.1		753
Australia	12.0	3.4	2.4	79.2		694	9.2	3.1	2.9	81.7		925
France	6.2	4.5	2.9	82.6		371	7.1	2.9	2.1	85.2		382
Canada	9.7	2.9	2.5	81.1		1 013	8.1	2.3	3.8	84.6		1 056
Japan	2.8	3.8	1.3	90.6		654	3.4	1.7	1.4	93.3		646

QUESTION N 3

A cup full of water and a similar cup full of petrol were placed on a table near a window on a hot sunny day. A few hours later it was observed that both cups have less liquid in them but that there was less petrol than water. What does this experiment prove?

A. All liquids evaporate.
B. Petrol gets hotter than water.
C. Some liquids evaporate faster than others.
D. Liquids will only evaporate in sunshine.
E. Water gets hotter than petrol.

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

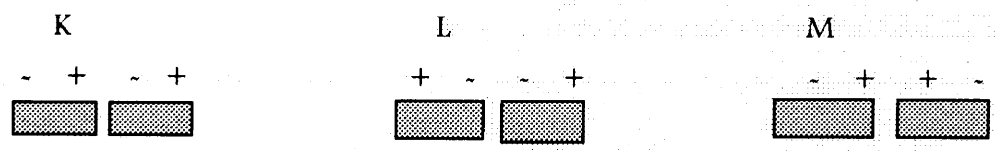
	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	**11.7**	**35.9**	**20.1**	**30.7**	**14.0**	**621**	**14.2**	**34.8**	**20.1**	**12.7**	**15.6**	**543**
Iran	10.2	13.1	63.5	5.3	7.3	476	8.9	12.0	66.9	4.8		464
Colombia	7.8	34.5	44.2	8.9	2.7	340	5.7	43.3	42.3	4.0	3.7	321
Thailand	13.3	28.3	47.4	8,7	1.3	725	12.5	32.1	45.1	6.5	2.7	704
Australia	4.9	21.5	65.8	5.7	2.0	690	5.1	19.0	70.5	2.5	1.9	895
France	6.9	13.9	64.9	6.7	2.9	384	4.4	12.. 9	75.0	3.4	2.4	360
Canada	7.7	15.4	69.7	3.1	1.5	1 015	4.4	13.4	78.2	1.0	2.0	1 044
Japan	7.0	56.2	27.6	4.7	3.6	652	6.4	56.4	30.2	2.4	4.3	655

Both questions N 3 and K 14 require a knowledge of evaporation. In the case of Question N 3, the South African performance was less than half the achievement level achieved for Question K 14. There is an apparent incorrect concept shown in Question N 3 in that there appears to be an assumption that bodies get hotter the longer they are exposed to the sun, without regard to the common ambient temperature. The Japanese students and those of several other nations appear to have made the same incorrect assumption. Question K 14 appeared to present no widespread problems, most countries scoring 60% or more at both grade levels.

5.7.4.4 Physics - Electricity - Questions G 7, K 13 and M 12

QUESTION G 7

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



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

A. Only as in K

B. Only as in L

C. Only as in M

D. None of these ways would work.

PERFORMANCE EXPECTATIONS: Processing complex information

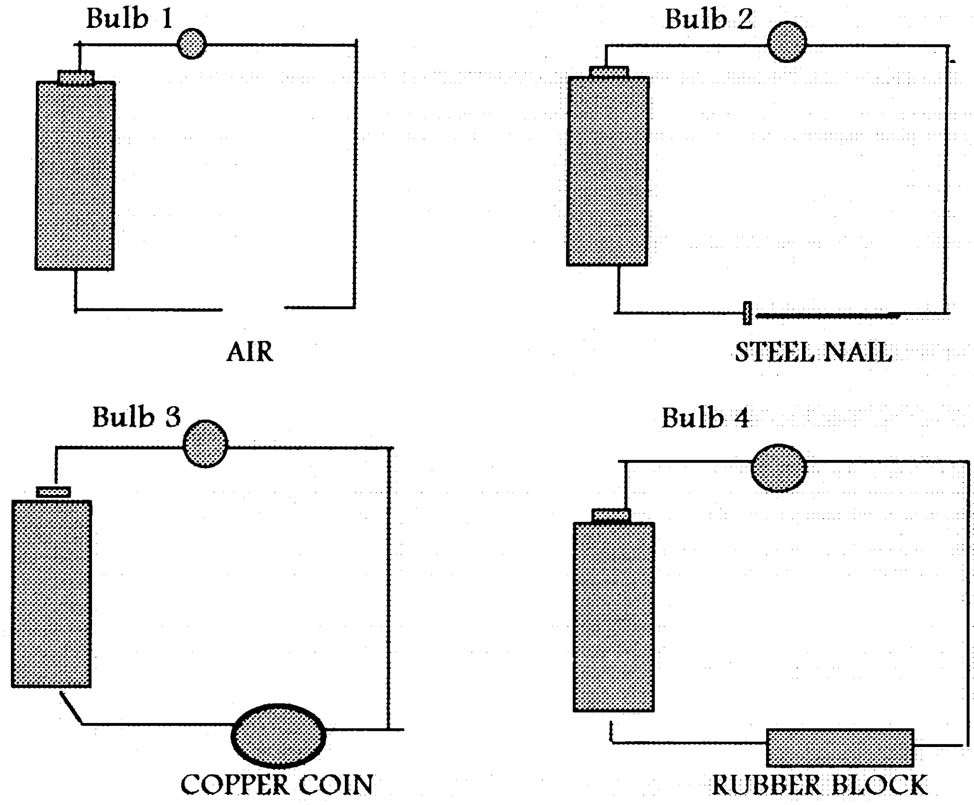
CURRICULUM FIT Standard 5 - No fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	47.8	15.3	18.2	16.6		1 973	58.0	10.7	14.5	15.0		1 651
Iran	58.0	9.9	14.2	16.4		1 410	66.6	7.3	13.8	11.5		1 385
Colombia	72.5	9.0	5.0	9.2		1 005	76.3	8.1	3.8	6.5		991
Thailand	90.8	2.6	3.4	2.9		1 514	93.7	1.4	2.8	1.8		2 185
Australia	85.6	5.2	3.9	4.5		2 111	90.6	3.5	2.5	3.2		2 706
France	87.0	3.3	1.9	4.0		1 099	89.1	2.8	2.5	5.1		1 114
Canada	88.1	4.0	3.6	4.0		3 048	89.9	3.1	3.0	3.7		3 145
Japan	92.4	2.7	2.4	2.4		1 958	93.7	1.5	1.8	2.9		1 947

Question G 7 is an electricity question falling within the ambit of every day experience for a large majority of students. The students were asked to identify the correct way to place batteries in a torch. With the exception of South Africa, Question K 13 was a high scoring question for all the participating nations dealing with the concept of electrical conductivity and the concept of conductors and insulators.

QUESTION K 13

The following diagrams show a torch battery and a bulb connected by wires to various substances.



Which of the bulbs will light?

A. 1 and 2 only **B.** 2 and 3 only **C.** 3 and 4 only
D. 1, 2 and 3 only **E.** 2, 3 and 4 only

PERFORMANCE EXPECTATIONS: Processing complex information

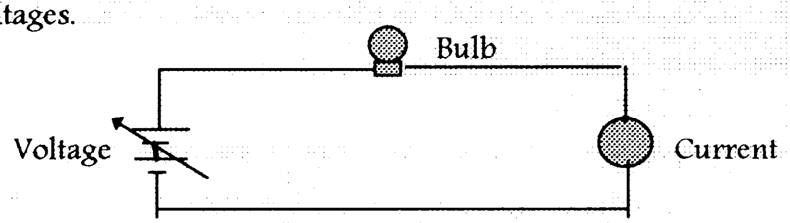
CURRICULUM FIT Standard 5 - No fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	23.1	25.1	28.7	9.1	11.2	680	15.0	36.9	25.3	7.2	12.1	545
Iran	8.5	59.0	11.9	7.3	11.8	465	8.3	59.1	8.7	7.9	15.3	463
Colombia	7.4	47.2	8.7	6.1	12.9	332	12.0	62.6	5.2	5.2	10.6	338
Thailand	3.3	73.4	4.3	8.9	8.2	739	3.9	77.7	3.1	7.9	4.5	753
Australia	7.0	72.7	5.4	5.8	8.2	694	4.0	83.0	3.4	5.6	3.5	925
France	5.9	67.1	7.1	4.7	13.8	371	3.9	79.0	4.1	3.0	8.7	382
Canada	6.1	75.9	5.8	4.3	7.4	1 013	5.4	78.9	5.0	4.0	6.1	1 056
Japan	2.5	88.3	3.4	1.5	3.9	654	2.4	91.8	1.0	1.9	2.9	646

In South Africa's case Question K 13 is one of those in which a clear difference in scores between Upper Grade (where conductivity is in the syllabus) and Lower Grade (where is is not in the syllabus). As can be seen in the data table Question K 13 is one of the few questions where the Standard 6 achievement was significantly higher than the Standard 5 achievement. Even in this case, though, it is debatable whether or not the concept of conductors and insulators is clearly understood since a substantial proportion of South African students are under the misapprehension that rubber (distracter C) is a conductor.

QUESTION M 12

Some students used an ammeter to measure the current in the circuit for different voltages.



The table shows some of the results. Complete the table

Voltage (volts)	Current (milliamperes)
1.5	10
3.0	20
6.0	.*

PERFORMANCE EXPECTATIONS: Problem solving

CURRICULUM FIT Standard 5 - No fit Standard 6 - No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	10	70	79	90	99	N	10	70	79	90	99	N
South Africa	0.7	3.9	2.3	0.3	92.8	380	0.9	3.9	1.9	0.1	93.2	296
Iran	23.3	36.7	21.8	1.3	16.9	468	38.2	32.8	13.0	1.4	14.5	458
Colombia	18.2	38.5	20.5	1.1	21.7	332	23.1	40.2	13.9	0.3	22.5	330
Thailand	51.7	31.6	9.7	0.1	7.0	743	55.5	32.2	7.6	-	4.8	728
Australia	47.5	36.3	4.8	1.0	10.4	715	56.9	30.6	4.6	0.8	7.1	888
France	57.0	21.8	7.5	0.2	13.5	378	69.6	18.0	8.1	-	4.3	372
Canada	37.5	42.3	13.2	0.4	6.6	1 016	51.7	35.4	8.5	0.5	3.9	1 048
Japan	67.9	24.0	5.8	-	2.3	652	72.9	20.3	5.8	0.2	0.8	646

EXPLANATION OF THE CODES 10 is a correct answers. 70 and 79 are incorrect answers. 90 and 99 indicates that a question either not answered or the answer was indecipherable.

Question M 12, a Free Response Item, is based on Ohm's Law, which does not appear in the Standard 5 or 6 curriculum. However, the very low response of any intelligible answers suggests that few students could even begin to find a starting point for this Free Response problem.

5.7.5 LIFE SCIENCES - Insects - Question I 11

QUESTION I 11

What features do all insects have?

	Number of LEGS	Number of BODY DIVISIONS
A.	2	4
B.	4	2
C.	6	3
D.	8	3

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	22.0	18.9	27.1	18.7		697	23.1	24.7	24.6	17.8		562
Iran	17.0	25.0	28.8	22.0		475	18.2	30.0	27.6	22.2		463
Colombia	17.6	23.9	18.1	23.8		325	18.8	25.5	19.9	15.7		328
Thailand	9.4	25.9	44.0	19.0		770	8.2	28.3	43.4	18.3		771
Australia	6.4	19.2	52.2	15.1		680	5.8	21.6	52.4	13.9		894
France	6.9	32.1	41.6	7.6		380	6.3	36.6	35.4	7.5		364
Canada	9.1	27.5	47.3	12.1		1 033	8.7	26.8	49.4	11.4		1 053
Japan	2.7	23.0	69.4	4.6		645	2.2	13.2	81.8	2.7		669

This taxonomy question was, in general, not well handled by most nations, and in many cases an insect was identified as having four legs and two body divisions (distracter B).

5.7.6 CHEMISTRY

5.7.6.1 Chemistry - Mixtures and Compounds - Questions M 10 and Q 14

QUESTION M 10

Which of the following is NOT a mixture?

A. Air B. Blood C. Orange juice D. Salt

PERFORMANCE EXPECTATION: Processing simple information

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	35.9	16.8	19.2	20.2		596	36.6	19.0	18.1	20.9		553
Iran	25.6	16.1	22.7	34.4		468	21.3	15.6	30.4	31.7		458
Colombia	40.7	15.2	16.7	24.6		332	38.4	15.0	16.4	21.5		330
Thailand	31.1	23.3	9.4	35.0		734	33.0	17.6	12.0	36.3		728
Australia	18.2	17.4	17.0	47.4		715	18.2	15.5	18.2	46.6		888
France	15.6	14.7	19.9	46.1		378	12.7	15.9	9.7	59.9		372
Canada	26.2	13.9	8.2	51.1		1 016	15.1	12.7	7.6	64.2		1 048
Japan	14.4	19.7	11.0	52.8		652	9.6	16.3	11.4	62.6		646

Whilst there were a regular number of responses from other countries that offered the Air distracter (A) as not being a mixture, in South Africa's case, more than one third of the sample chose air as the correct answer. This lack of basic chemical knowledge does, however, appear to be fairly widespread internationally and is not confined to South Africa.

QUESTION Q 14

A mixture of powdered iron and sulphur is heated. What will be formed?

A. A single element B. Two other elements C. A solution
D. An alloy E. A compound

PERFORMANCE EXPECTATIONS Processing complex data

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D	E	N	A	B	C	D	E	N
South Africa	9.8	15.8	40.0	10.1	14.5	554	8.1	15.2	29.0	4.3	38.7	483
Mexico	13.2	5.9	6.8	7.4	58.9	751	9.1	4.6	14.0	9.0	56.4	688
Colombia	8.0	4.0	8.3	3.7	46.3	335	7.2	3.9	8.8	7.1	41.7	341
Thailand	7.4	3.3	10.4	50.5	27.2	696	5.1	4.9	4.0	37.1	45.4	687
Australia	11.8	7.0	30.8	13.3	33.4	688	6.5	6.8	24.6	12.4	46.7	926
France	10.4	6.1	11.1	35.5	23.4	375	4.7	4.3	27.8	39.2	15.1	370
Canada	15.0	6.5	23.9	21.3	30.2	1 024	10.8	3.6	33.2	20.9	27.9	1 029
Japan	7.9	9.3	11.3	24.1	46.0	646	7.5	3.8	1.1	3.5	83.8	641

Almost without exception South Africa's results for this question (Q 14) were the lowest of all the participating nations. Students have obviously failed to grasp the fundamental concepts of compounds and mixtures. For this question also the South African Upper Grade significantly outscored the Lower Grade.

SIGNIFICANCE

$p = 14.5,\ n = 554$

$Sp = \sqrt{\frac{p(1-p)}{n-1}} = 0.042$

$p = 38.7,\ n = 483$

$Sp = \sqrt{\frac{p(1-p)}{n-1}} = 0.276$

Confidence interval at the 5% level is given by:

$Ci = p +/- 1.96 \times Sp = +/- 0.082$

$= 14.46 \rightarrow 14.55$

$Ci = p +/- 1.96 \times Sp = +/- 0.541$

$= 37.26 \rightarrow 39.24$

There is no overlap between the confidence fields therefore the difference between the Upper Grade and Lower Grade scores is significant at the 5% level.

This is a highly significant difference and is exceptional in that it appears to reflect an example of a situation where a Grade 7 'non-fit' item shows a substantially lower level of achievement than a Grade 8 curriculum 'fit' item.

5.7.6.2 Chemistry - Energy of Reactions - Questions M 13 and Q 15

QUESTION M13

When oil is burning, the reaction will

A. only release energy;
B. only absorb energy;
C. neither absorb nor release energy;
D. sometimes release energy and sometimes absorb energy depending on the oil.

PERFORMANCE EXPECTATIONS: Handling complex data

CURRICULUM FIT Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	18.0	27.9	13.0	36.0		612	15.4	31.1	15.6	32.0		556
Mexico	27.3	15.8	14.3	38.5		757	29.1	15.6	13.1	38.7		699
Colombia	23.6	9.2	11.7	51.1		332	19.9	8.5	8.3	52.4		330
Thailand	30.2	11.6	5.9	50.7		734	38.6	11.9	3.2	45.4		728
Australia	46.6	15.9	7.3	28.6		715	53.6	13.0	8.4	23.5		888
France	52.6	13.0	6.1	25.1		378	65.5	7.4	5.2	19.2		372
Canada	43.4	12.6	8.2	34.6		1 016	53.1	9.2	7.3	29.6		1 048
Japan	56.5	14.3	5.9	22.6		652	64.2	10.4	4.3	20.5		646

The misapprehension that some oils burn exothermically whilst other burn endothermically is both widespread and indicative of misconcepts of the process of combustion and the energy transfers in chemical processes.

QUESTION Q 15

Which is NOT an example of a chemical change?

A. Boiling water B. Rusting iron C. Burning wood D. Baking bread.

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	21.8	21.1	17.1	30.2		555	25.6	19.5	14.0	35.4		480
Mexico	24.8	18.3	11.4	38.7		751	28.7	20.3	11.2	31.4		688
Colombia	17.4	11.3	12.5	28.4		335	18.4	9.3	12.6	27.7		341
Thailand	22.9	18.0	14.0	43.6		696	16.4	18.6	11.9	49.8		687
Australia	36.7	20.9	16.2	24.0		688	46.9	13.4	10.2	27.5		926
France	20.6	18.1	11.9	39.0		375	18.6	28.0	12.6	35.4		370
Canada	36.6	16.9	10.5	32.3		1 024	37.8	13.8	12.4	33.5		1 029
Japan	19.0	21.2	14.5	43.9		646	54.6	9.4	4.3	31.3		641

On a world wide basis this question proved difficult. The recognition of a chemical change is fundamental to early understanding of chemistry and failure to do so reveals a potentially serious shortcoming in the teaching of chemistry.

5.7.6.3 Chemistry - Atomic Theory - Questions O 15 and G 10

QUESTION O 15

If a neutral atom loses an electron, what is formed?

A. A gas B. An ion C. An acid D. A molecule

PERFORMANCE EXPECTATIONS : Understanding complex information

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	46.6	14.3	20.8	14.4		619	45.8	12.2	23.6	15.0		521
Mexico	18.0	14.4	9.8	54.6		753	18.5	26.7	7.1	43.4		697
Colombia	17.2	31.1	5.4	38.5		327	8.0	40.0	7.2	38.2		329
Thailand	19.0	9.7	11.5	58.5		707	20.2	15.4	8.0	54.6		703
Australia	29.9	12.6	15.0	40.6		694	18.1	30.6	11.3	37.9		893
France	20.3	18.5	17.6	33.6		374	11.0	40.3	6.1	37.7		370
Canada	24.3	19.5	12.0	43.2		1 042	24.1	25.3	9.7	40.3		1 014
Japan	9.1	27.3	14.3	48.0		648	13.7	32.5	16.0	37.5		652

Question O 15 is also concerned with the fundamental concepts of chemistry and universal shortcomings are readily identifiable. The outcomes of this question underline the general trend in the TIMSS test papers that holds for all participating nations, that Chemistry is the weakest section of all the sciences in terms of achievement. Only a relatively small proportion of students in any country were able to identify the conditions under which an ion forms. Whilst this item was established as being within the curriculum, experience suggests that the concept of ions in particular is a topic that is only touched on lightly or avoided in many science classrooms. Even with this shortcoming, the distracter that attracted the most answers - a molecule- also reveals a serious shortcoming in the vocabulary and knowledge of middle school science.

Question G10 is an embargoed question that also investigates students' concepts and knowledge of atomic theory in which students generally did not perform at all well. Whilst it must be conceded that relative to many questions, the South African performance in this question was above average there are still indications that a large proportion of students, both South African and from other countries do not have a clear understanding of what an atom is in relation to matter.

QUESTION G 10 This is an embargoed question.

PERFORMANCE EXPECTATIONS Processing complex information

CURRICULUM FIT Standard 5 No fit Standard 6 Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	22.9	12.9	41.9	19.9		1 972	23.4	13.8	42.2	18.2		1 648
Iran	24.1	16.0	42.8	14.0		1 410	21.9	16.9	47.1	12.2		1 383
Colombia	25.5	7.4	51.7	8.9		1 005	21.8	12.6	52.8	6.0		991
Thailand	40.4	14.7	27.1	16.6		2 198	27.3	18.1	37.4	15.7		2 185
Australia	27.9	13.7	46.4	10.7		2 111	18.3	15.2	57.7	7.6		2 706
France	30.9	9.3	39.1	11.4		1 135	21.4	19.1	47.6	7.3		1 114
Canada	27.5	10.7	49.5	11.5		3 048	21.2	10.2	56.7	11.3		3 145
Japan	27.1	10.5	42.4	19.4		1 958	21.2	10.2	58.0	10.5		1 947

5.7.7 ENVIRONMENTAL SCIENCES - Questions G 12 and N 5

QUESTION G 12

PERFORMANCE EXPECTATIONS: Processing simple information

CURRICULUM FIT: Standard 5 No fit Standard 6 No fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	**16.1**	**29.8**	**18.8**	**32.6**		**1 971**	**14.6**	**33.2**	**21.6**	**28.5**		**1 650**
Iran	12.0	11.4	27.7	46.2		1 410	11.5	14.1	32.6	40.3		1 383
Colombia	10.6	12.8	19.4	51.4		1 005	10.9	14.2	20.4	47.2		991
Thailand	16.1	5.2	19.6	58.4		2 198	12.4	4.9	21.9	59.9		2 185
Australia	9.9	13.6	21.4	53.8		2 111	12.4	9.8	17.3	59.6		2 706
France	12.3	16.5	34.0	33.9		1 135	13.3	13.2	30.6	41.7		1 114
Canada	9.9	8.9	18.1	62.3		3 048	9.1	7.1	18.0	65.0		3 145
Japan	10.0	10.8	46.4	3.0		1 958	8.0	9..3	48.4	33.8		1 947

QUESTION N 5

One of the principal causes of acid rain is

A. waste acid from chemical factories being pumped into rivers.

B. acid from chemical laboratories evaporating into the air.

C. gases from burning coal and oil dissolving in water in the atmosphere.

D. gases from air conditioners and refrigerators escaping into the atmosphere.

PERFORMANCE EXPECTATIONS: Processing complex data

CURRICULUM FIT: Standard 5 - Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	**25.4**	**38.3**	**21.8**	**10.5**		**625**	**24.8**	**38.7**	**21.9**	**11.3**		**540**
Iran	40.6	25.8	24.3	6.8		476	40.5	31.0	23.3	4.1		464
Colombia	30.2	33.0	24.6	9.9		340	23.7	34.3	30.7	9.0		321
Thailand	27.3	17.3	51.3	3.6		725	17.8	16.6	61.6	3.3		704
Australia	21.5	32.3	32.1	12.4		690	19.1	31.1	41.9	7.1		895
France	.	.	.	.		.	.	.	.	.		.
Canada	28.8	31.3	27.0	10.8		1 015	31.2	29.7	31.2	6.4		1 044
Japan	25.9	23.3	37.6	12.9		652	24.8	17.7	46.1	11.2		655

For the past five years Environmental Sciences in South Africa have received considerable attention and class time, particularly in what were the old Department of Education and Training [DET] schools. However, the South African performance in this aspect of the TIMSS question papers appears to indicate that relatively little knowledge has transferred to the students in the form of knowledge that they are able to use.

Question G 12, which is embargoed, enquires into renewable and non-renewable resources. The students were asked to identify a non-renewable resource. Less than one third of the South African students were able to identify coal as being non-renewable. In view of the very substantial South African coal reserves and the high public image of coal based companies such as SASOL, it might reasonably be expected that better results for this question could have been expected. Only Iran, with no established coal reserves, scored as low as South Africa. As can be seen, the proportion of students gaving the correct answer was almost double that of South Africa.

Question N 5 deals with acid rain, an issue that has received substantial publicity and one with which South African students should be familiar both through school and through the public media. Internationally, though, there seems to be a widely held concept that acid rain is caused by industry or by chemical evaporation.

5.7.8 SELECTED QUESTIONS OF PARTICULAR INTEREST

5.7.8.1 Infallibility of Scientists - Question P 7

This question was particularly interesting in that there was a sub-agenda to the question concerning the 'faith' that school students have in science and Scientists.

QUESTION P 7

Whenever Scientists carefully measure any quantity many times, they expect that

A. all of the measurements will be exactly the same.

B. only two of the measurements will be exactly the same.

C. all but one of the measurements will be exactly the same.

D. most of the measurements will be close but not exactly the same.

PERFORMANCE EXPECTATIONS: Science in the everyday world

CURRICULUM FIT Standard 5: Fit Standard 6: Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	**26.1**	**22.1**	**21.2**	**25.1**		**614**	**28.2**	**25.2**	**18.0**	**23.9**		**489**
Iran	42.5	11.3	12.4	31.6		465	41.2	8.8	8.9	38.8		464
Colombia	47.9	3.8	5.1	32.1		333	46.8	3.9	4.7	39.0		341
Thailand	8.0	3.5	15.7	70.4		696	7.0	3.2	10.8	77.0		687
Australia	27.6	5.0	4.7	62.1		687	28.9	3.6	3.5	62.9		919
France	38.5	7.2	6.6	42.5		371	39.2	1.9	5.2	50.6		370
Canada	29.8	4.5	3.2	60.6		1 030	34.0	3.1	3.8	58.4		1 030
Japan	50.4	9.9	8.5	29.9		646	44.9	7.2	7.8	39.1		641

The findings were that despite education in the scientific method and, frequently being exposed to the 'craft' and 'technology' injunction of 'measure twice and cut once', school students appear to remain convinced that measurement is a precise operation (distracters A and C). This view, with the significant exception of Thailand, permiated the responses of all the participants in TIMSS.

5.7.8.2 The 'Vitamin' question - Question H 5

QUESTION H 5 (See Appendix 1)

People get energy from the food they eat. Where does the energy stored in food come from?

A. Fertilizers B. The Sun C. Vitamins D. The soil

PERFORMANCE EXPECTATIONS: Processing complex data

CURRICULUM FIT Standard 5 - No Fit Standard 6 - No Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	8.5	12.9	49.5	26.5		1 920	6.4	16.4	43.3	31.9		1 639
Iran	4.4	47.6	44.8	2.4		1 381	6.1	53.7	34.5	5.2		1 362
Colombia	5.1	16.9	45.8	28.0		998	5.2	21.6	38.9	32.5		980
Thailand	5.9	19.2	57.4	17.1		2 158	5.8	23.4	46.7	23.7		2 145
Australia	3.8	19.0	61.2	13.9		2 093	2.7	29.1	55.2	12.5		2 694
France	4.8	7.0	66.9	17.7		1 128	4.5	6.5	68.5	18.7		1 117
Canada	3.7	21.1	56.4	18.2		3 079	4.6	22.0	54.1	18.3		3 101
Japan	9.5	50.8	13.2	25.8		1 952	9.0	53.2	10.1	27.3		1 961

The trend shown by the above nations in selecting Vitamins (distracter C) as the answer to question H 5 is displayed virtually throughout the list of nations reported on in the TIMSS international reports. If the copy of an advertisement attached as Appendix 1 is examined, the commercial message is absolutely clear: *vitamins = energy.* In the classroom situation, the education message of energy from the sun is overwhelmed by the advertising/commercial disinformation. It is noticeable that only Japan and Singapore achieved good results for this question. This question has the highest Difficulty Index (24.4 Upper Grade and 21.0 Lower Grade) of all the TIMSS questions owing to a media-induced misconcept. Similarly, a substantial number of countries opted for the sources of energy in food as the soil (distracter D) arguably because these countries are by and large agrarian.

5.7.9 QUESTIONS WITH A TECHNOLOGY COMPONENT

Since Technology, as a school subject focus, is of growing concern in South Africa, an analysis of the technological components of the TIMSS test instruments is shown below to determine South African performance in this field.

Table 5.13 Comparative performances of questions with a technological content

Question Number	Grade/ Standard	South African scores : per cent correct	International scores : per cent correct	Topic of the question
A6	LG - 5 UG - 6	45.5 45.8	74.2 77.5	Average of scores
A9	LG - 5 UG - 6	38.6 37.7	70.8 77.8	Combustion
B2	LG - 5 UG - 6	26.3 38.0	49.2 57.6	Energy and combustion
B6	LG - 5 UG - 6	67.4 68.6	80.0 84.4	Colour and reflection
C2	LG - 5 UG - 6	31.0 36.1	72.2 77.3	Pie chart interpretation
C11	LG - 5 UG - 6	27.3 26.3	42.2 46.5	Greenhouse effect
C12	LG - 5 UG - 6	29.2 28.9	50.0 53.8	Fossil fuels
D4	LG - 5 UG - 6	23.0 20.9	51.5 58.3	Energy conversions
D11	LG - 5 UG - 6	44.6 51.1	81.6 84.7	Units of mass
D12	LG - 5 UG - 6	38.7 40.3	68.1 72.5	Estimate of length
E12	LG - 5 UG - 6	23.1 24.8	48.4 54.2	Underground caves
F5	LG - 5 UG - 6	40.8 39.1	77.2 81.6	Oxygen at altitude
F6	LG - 5 UG - 6	24.8 26.1	64.1 70.9	Corrosion
F10	LG - 5 UG - 6	23.7 24.3	50.0 55.3	Estimate length
G2	LG - 5 UG - 6	43.6 42.5	72.0 75.5	Estimate of length
G7	LG - 5 UG - 6	47.8 58.0	84.3 87.7	Torch batteries in series
G12	LG - 5 UG - 6	32.6 28.5	49.3 52.4	Renewable energy resources
H5	LG - 5 UG - 6	13.0 16.4	21.8 25.1	Energy from food

H7	LG - 5 UG - 6	21.4 21.0	62.8 67.8	Interpretation of Histogram
I13	LG - 5 UG - 6	21.7 23.3	54.3 61.1	Thermometer ranges
I14	LG - 5 UG - 6	29.0 28.4	50.3 53.2	Levers in the body
I16	LG - 5 UG - 6	42.0 39.8	80.2 83.3	Conduction of heat
I17	LG - 5 UG - 6	26.3 26.1	37.1 40.9	Energy source for the Water Cycle
K13	LG - 5 UG - 6	25.1 36.9	68.7 76.8	Electrical conductivity
K15	LG - 5 UG - 6	25.6 21.0	54.2 61.6	Fossil fuels
L1	LG - 5 UG - 6	17.8 18.8	43.5 48.6	Moments
L7	LG - 5 UG - 6	28.1 27.3	66.8 70.3	Transmission of sound
L8	LG - 5 UG - 6	21.2 20.5	55.2 59.9	Estimate height
L11	LG - 5 UG - 6	40.7 41.5	30.7 34.2	Elastic bounce
M1	LG - 5 UG - 6	48.3 47.7	83.1 86.2	Estimate dial reading
M13	LG - 5 UG - 6	17.9 16.3	40.3 50.6	Energy and combustion
N5	LG - 5 UG - 6	21.8 21.9	30.8 35.1	Causes of Acid Rain
N8	LG - 5 UG - 6	27.9 31.0	67.7 71.5	Levers and balancing
N9	LG - 5 UG - 6	28.6 27.8	43.4 51.9	Separation by filtration
O1	LG - 5 UG - 6	14.6 13.9	50.8 58.4	Interpretation of line graph
P1	LG - 5 UG - 6	56.0 57.6	78.0 82.5	Distance travelled from line graph
P7	LG - 5 UG - 6	25.1 23.9	49.3 52.7	Repeated measurements - why?
P11	LG - 5 UG - 6	19.9 16.3	48.8 52.0	Estimate length
P12	LG - 5 UG - 6	34.0 32.9	65.6 69.5	Estimate number by rounding off
P17	LG - 5 UG - 6	27.5 31.5	79.2 82.2	Interpret table of weather data
Q13	LG - 5 UG - 6	22.8 23.7	52.4 59.1	Expansion of metals
R8	LG - 5 UG - 6	17.9 20.6	44.0 49.1	Interpretation of line graph

Free Response items				
N7	LG - 5 UG - 6	3.6 3.5	89.2 92.7	Combustion and oxygen
Q12	LG - 5 UG - 6	1.2 1.5	41.9 48.2	Torches and reflectors

This list of questions serves to emphasize the generally small difference between the South African Standard 5 and Standard 6 achievement. In eighteen of the forty-four questions shown, the Lower Grade (Standard 5) outscored the Upper Grade. With only a few exceptions, this group of questions averages out at higher scores than South Africa attained overall in the TIMSS tests. This selection of questions serves to confirm the overlap of fields between Mathematics and Science on the one hand and Technology on the other. Although Technology was not an integral part of the TIMSS testing concepts, the national Technology Forum would gain from a closer examination of these questions and their outcomes in terms of achievements.

Two of the questions in this table have been highlighted because of the anomalous performances that the South African students show. For Question L11, at both Lower and Upper Grade, the South African proportion of correct answers is higher than the international average. Question L11 is as follows:

Question L11

A rubber ball rebounds to half the height it drops. If the ball is dropped from a rooftop 18m above the ground, what is the total distance travelled by the time it hits the ground the third time?

A. 31.5m B. 40.5m C. 45m D. 63m

Examination of this question suggests that from a mathematics conceptual point of view it is not easy, in that firstly it requires the ability to visualize a chain of events; and secondly, in language terms, the question is long and complex and therefore for largely second language students, it is not easy. There is no readily available explanation why the South African students should have done relatively well in this question when internationally it proved to be in the top 10 per cent of the most difficult questions in the TIMSS question bank.

Furthermore, South African students performed fairly close to, but somewhat below, the international average for Question B6. This question required information about the reflection of light. Again, the South African students managed at a fairly competent level to handle the relative difficulty of this question despite the fact that the conceptual expectations were not straight forward.

5.7.10 THE HIGHEST AND LOWEST SCORING QUESTIONS - SCIENCE

5.7.10.1 The highest scoring questions - Science - Lower Grade - Questions B1 and B6

The highest scoring question for the South African sample was question B 1 which is an embargoed question enquiring into radiation of heat. 67.2% of South African students selected the correct answer to this question. The international index of difficulty was 80.4% correct.

The second highest scoring question for South Africa was question B 6. This question concerns the temperature of the layers of the earth. 62.9% of South African students were able to identify the core of the earth as being the hottest. Internationally 85.6% of students received a mark for this question.

5.7.10.2 The lowest scoring questions - Science - Lower Grade - Questions H5 and O 12

The two lowest scoring questions for the Standard 5 group were questions H 5 and O 12. Question H5 is on the embargo list but concerns the source of energy in our food. This question has already been discussed in paragraph 5.7.8.2 above. Question O 12 was the second lowest scoring question. This question, already discussed above in paragraph 5.7.1.1, concerns the composition of the atmosphere. The data is worth reconsidering in the light of the extremely low South African achievement at both grade levels.

QUESTION O 12

Air is made up of many gases. Which gas is found in the greatest amount?

A. Nitrogen B. Oxygen C. Carbon dioxide D. Hydrogen

	A	B	C	D	International Index of Difficulty	n
Standard 5	13.7	53.3	18.4	11.2	22.4	621
Standard 6	9.8	57.2	17.2	11.7	26.9	518

In terms of difficulty this question proved to be one of the more difficult questions internationally. Only 22.4% of students selected the correct answer.

5.7.10.3 The highest scoring questions - Science - Upper Grade - Questions B 1 and B 6

The two highest scoring questions for the Upper Grade, Standard 6, were the same two questions as for the Lower Grade, namely questions B 6 and B 1. Both are embargoed questions. A comparison of the results from the two grades is shown below:

Question B 1 - The hottest layer of the earth

	A	B	C	D	International Index of Dfficulty	n
Standard 5	13.2	11.1	62.9	9.7	85.6	2 525
Standard 6	14.4	10.8	60.5	11.8	87.0	2 151

Question B 6 - Radiation properties of surfaces.

	A	B	C	D	International Index of Difficulty	n
Standard 5	67.4	11.6	12.1	6.0	80.4	2 517
Standard 6	68.6	10.4	11.9	6.6	84.9	2 149

5.7.10.4 The lowest scoring questions - Science - Upper Grade - Questions O 12 and O 15

Question O 12 - Abundance of gases in the atmosphere. Discussed earlier in 5.71.1

	A	B	C	D	International Index of Difficulty	n
Standard 5	13.7	53.3	18.4	11.2	22.4	621
Standard 6	9.8	57.9	17.0	11.1	26.9	523

QUESTION O15

If a neutral atom loses an electron, what is formed?

A. A gas B. An ion C. An acid D. A molecule

PERFORMANCE EXPECTATIONS : Using simple data

CURRICULUM FIT Standard 5 - No Fit Standard 6 - Fit

	Standard 5 - TIMSS Lower Grade						Standard 6 - TIMSS Upper Grade					
	A	B	C	D		N	A	B	C	D		N
South Africa	46.6	14.3	20.8	14.4		619	45.8	12.2	23.6	15.0		521
Mexico	18.0	14.4	9.8	54.6		753	18.5	26.7	7.1	43.4		697
Colombia	17.2	31.1	5.4	38.5		327	8.0	40.0	7.2	38.2		329
Thailand	19.0	9.7	11.5	58.5		707	20.2	15.4	8.0	54.6		703
Australia	29.9	12.6	15.0	40.6		694	18.1	30.6	11.3	37.9		893
France	20.3	18.5	17.6	33.6		374	11.0	40.3	6.1	37.7		370
Canada	24.3	19.5	12.0	43.2		1 042	24.1	25.3	9.7	40.3		1 014
Japan	9.1	27.3	14.3	48.0		648	13.7	32.5	16.0	37.5		652

The second most difficult question for the Standard 6 [Grade 8] group was Question O 15, discussed in 5.7.6.3, and which enquires into the effect of the loss of an electron on a neutral atom and what is formed. The international difficulty level was 31.1% correct. It is worth commenting again that the degree of misconcept and uncertainty surrounding this question are very serious especially as this question deals with one of the fundamental concepts of chemistry.

5.7.11 THE INTERNATIONAL RANGE AND SPREAD OF DIFFICULTY OF MATHEMATICS AND SCIENCE QUESTIONS

The four tables below show the international distribution of difficulty of the Multiple choice questions for Mathematics and Science at the two grades/standards tested for all the international responses. The Free Response Items have not been listed but, even on an international basis they do tend to show a skewness towards the more difficult end of the achievement spectrum. The South African distribution of Indices of Difficulty shows a marked skewness to the left as might be expected from the low South African achievements.

Table 5.14 Upper Grade - The international distribution of difficulty of Mathematics questions

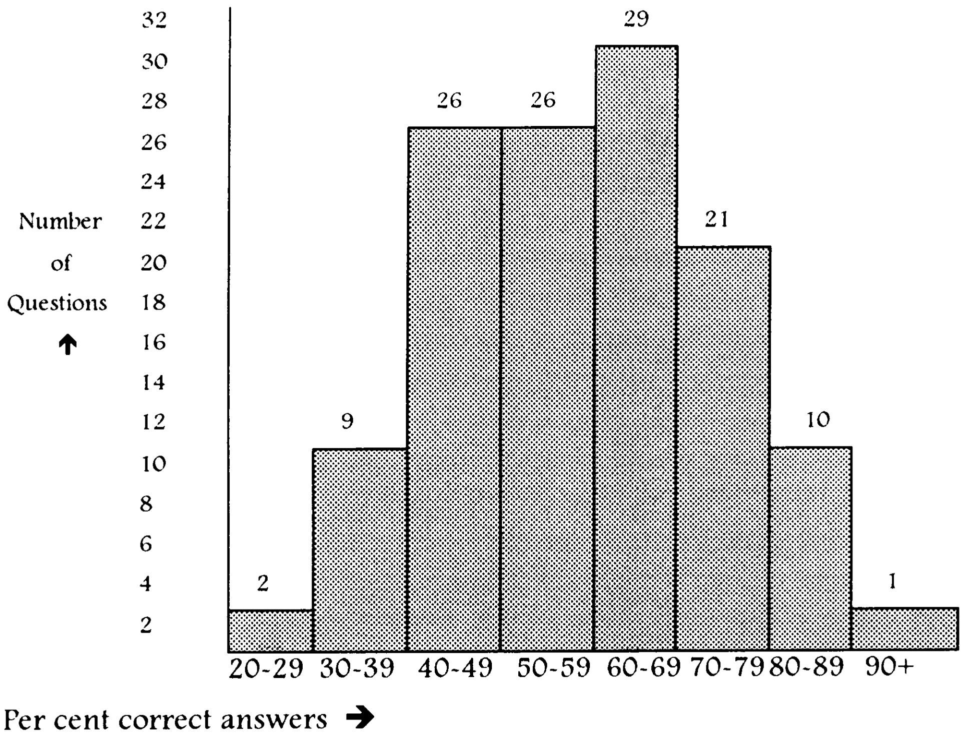


Table 5.15 Lower Grade - The international distribution of difficulty of Mathematics questions

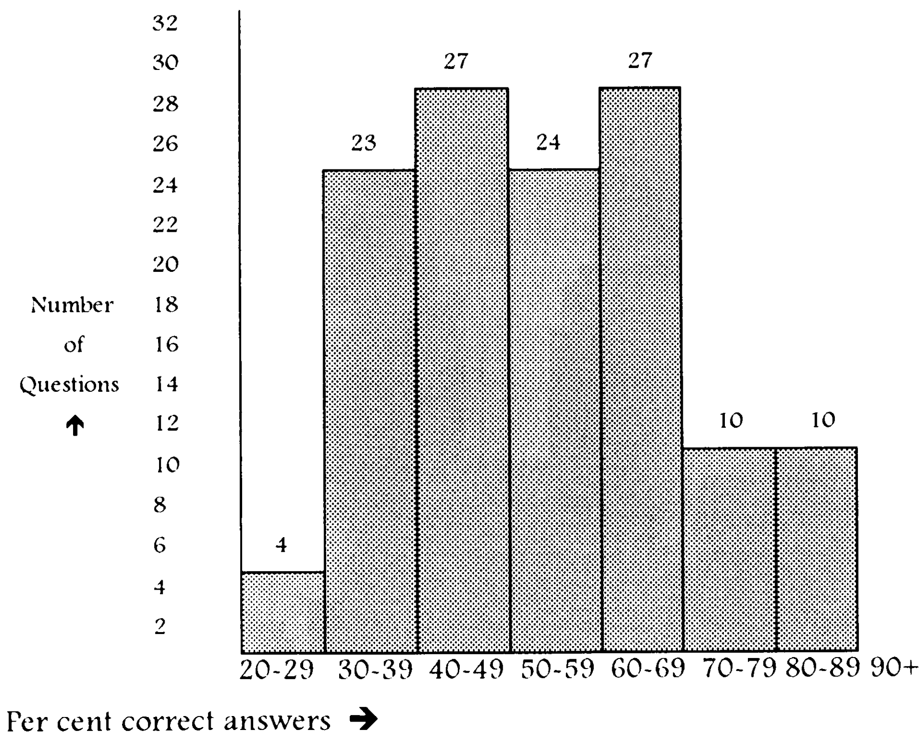


Table 5.16 Upper Grade - The international distribution of difficulty of Science questions

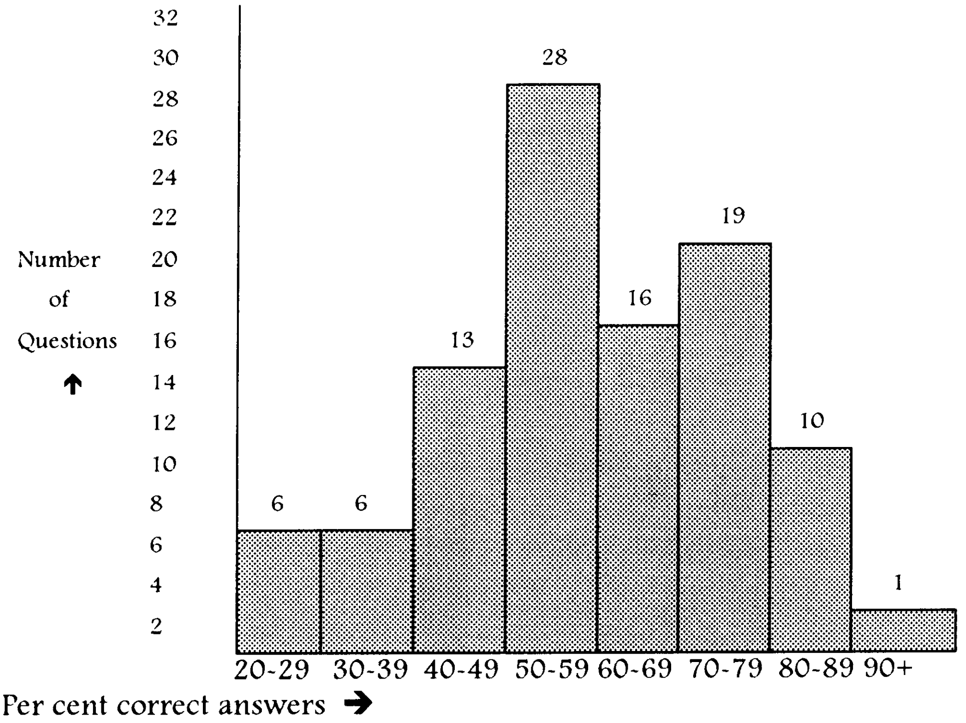
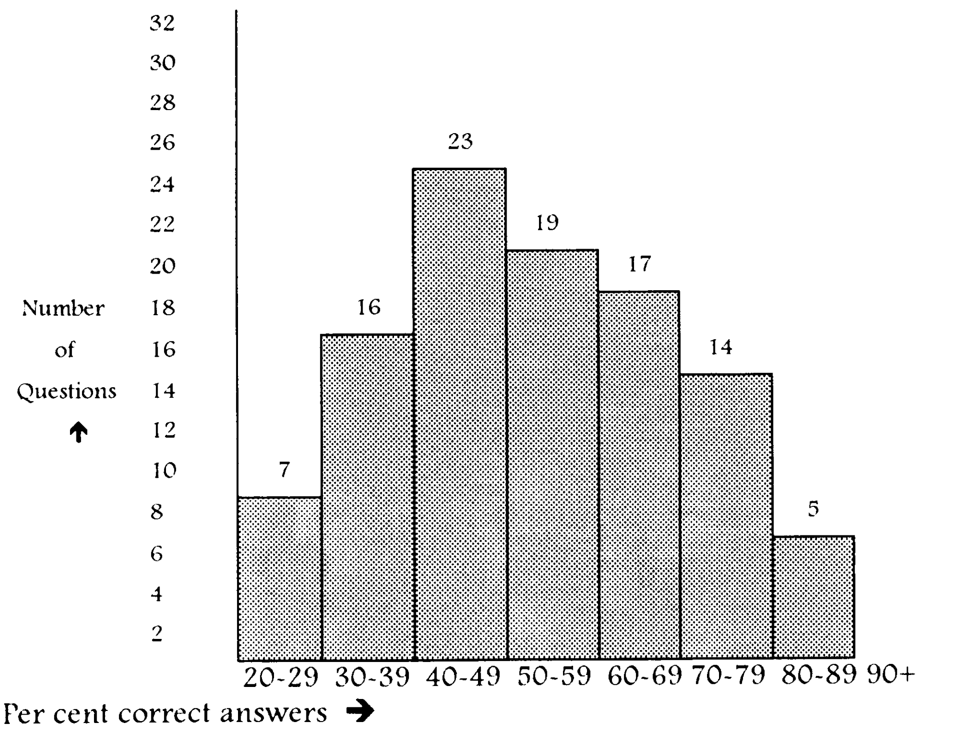


Table 5.17 Lower Grade - The international distribution of difficulty of Science questions



5.7.12 OVERVIEW OF THE SCIENCE SECTIONS OF TIMSS

As was the case with Mathematics, the Science sections of the TIMSS test instruments, performances were generally unsatisfactory with the exception of a few questions in which South African students scored over 55 per cent correct answers in either of the grades.

It is also very noticeable how rarely, in terms of aggregate, the Standard 6 students scored more than the Standard 5 students.

5.8 CONCLUDING OBSERVATIONS

The analysis of the selection of responses to the TIMSS Mathematics and Science questions in this chapter serves to highlight two basic educational problems in South Africa. The first of these is that fundamental concepts, such as mixtures and compounds, molecules, atoms and ions, are frequently confused. The second is perhaps more serious, pedagogically. There are extremely few indications of problem solving abilities as can be deduced from the outcomes of the Free Response questions. This problem of lack of skills in problem solving is discussed more fully in Chapter 7. Both these problem areas serve as indicators that the South African teaching 'method' focuses too heavily on rote learning and that insufficient attention is given to concept formation and problem solving skills (see 2.1.1).

CHAPTER 6

A PROFILE OF THE TIMSS STUDENT POPULATION AS SHOWN IN THE RESPONSES TO THE TIMSS QUESTIONNAIRE

6.1 THE TIMSS APPROACH TO TESTING

In order to accumulate evidence to support or challenge the general validity of test scores, such as those of the Third International Mathematics and Science Study discussed in Chapter 5, further evaluation instruments may be utilized. Such general instruments are usually grouped together in one of three categories:

- Content-related evidence;
- Criterion-related evidence; and
- Construct-related evidence.

Table 6.1 (Gronlund and Linn, 1990: 51) serves to define these three categories more fully:

Figure 6.1 Approaches to test validation

	PROCEDURE	MEANING
CONTENT-RELATED EVIDENCE	Compare the test tasks to the test specification describing the task domain under consideration.	How well the sample of test tasks *represents* the domain of tasks to be measured.
CRITERION-RELATED EVIDENCE	Compare test scores with another measure of performance obtained at a later date (for prediction) or with another measure of performance obtained concurrently (for estimating present status).	How well test performance *predicts* future performance or *estimates* current performance on some valued measures other than the test itself (called a *criterion*).

CONSTRUCT-RELATED EVIDENCE	Establish the meaning of the scores on the test by controlling (or examining) the development of the test, evaluating the relationships of the scores with other relevant measures, and experimentally determining what factors influence test performance.	How well test performance can be interpreted as a meaningful measure of some characteristic or quality.

As Gronlund and Linn (1990: 50) observe, what is important is that,

> Although these categories help emphasise particular needs for evidence to support specific kinds of interpretations, they are interrelated and all contribute to an overall evaluation of the degree of any given interpretation of scores on a test or other evaluation instrument.

As seen in the previous chapter, as well as in the acronym TIMSS, the primary concern of both the Third International Mathematics and Science Study and this thesis is with content-related and criterion-related evidence. However, at least some of the logical analyses of the meaning of the scores can be supplemented by what in the context of TIMSS can loosely be described construct-related evidence concerned with such extraneous factors as home and school envrronment, classroom practices and student attitudes, as well as extracurricular cultural and scholastic activities that may influence test performance. These other significant factors which may impact on achievement are the focus of this chapter.

6.1.1 THE SOURCE OF THE DATA

In addition to the ninety-minute achievement test in Mathematics and Science which in Brown's terminology (1980: 209) is:

> A test, in plain, ordinary words, [which] is a method of measuring a person's ability or knowledge in a given area.

The participating students in TIMSS were also required to complete a comprehensive questionnaire which dealt essentially with their biographical details and attitudes towards Mathematics and Science. This questionnaire, which includes behavioural and attitudinal items, comes closer to Caroll's definition (Bachman, 1990: 20) of a test as:

> A psychological or educational test [which] is a procedure designed to elicit certain behaviour [performances] from which one can make inferences about certain characteristics of an individual [or a sample population].

The purpose of the TIMSS questionnaire, therefore, is complementary to that of the achievement tests; both serve to identify the unique characteristics and similarities of the TIMSS population groups which participated in this major international study.

> Across the world, teachers and their students engage in the studies of Mathematics and the Sciences as they have for generations. It is widely believed that Mathematics and Science are objective and universal, transcending national and cultural differences. But what students and teachers experience is not pure *Mathematics and Science* but *school Mathematics and Science*. School Mathematics and Science, are Mathematics and Science as they are conceptualized, represented, structured and sequenced to share with the next generation through the common experience of schooling. Like all of education - which is the common means of transmitting a nation's culture to its next generation - school Mathematics and Science is profoundly cultural.
>
> (TIMSS 1996 (a): 9)

6.2 GENDER AND AGE DISTRIBUTION OF THE LOWER AND UPPER GRADE SAMPLES

In terms of gender, from the Lower Grade student records, 53.1 per cent are girls and 45.9 are boys. At the Lower Grade fifty-one students (1.0%) failed to complete this question. For the Upper Grade the proportions are

51.5 per cent female and 46.7 per cent male. Seventy-eight students (1.8%) failed to answer the question regarding gender in the Upper Grade.

Table 6.1 Gender distribution of the sample - South African data

(NOTE: For all the tables that follow in this chapter, the notation Dnr indicates 'Did not respond'.)

Grade	Female	Male	Dnr
National birth figures (1991) as registered	49.88% 268 367	50.12% 269 632	
Lower - Standard 5	53.1%	45.9%	1.0%
	2 808	2 428	51
Upper - Standard 6	51.5%	46.7%	1.8%
	2 243	2 031	78

This apparent imbalance in numbers, of females over males, may be typical of many developing countries where boys, in deep rural situations, are obliged to involve themselves in traditional male responsibilities such as herding livestock. More important perhaps, in the South African context, is the fact that in the years preceding the 1995 TIMSS testing, predictably more boys than girls dropped out of school to participate in political events and activities. The Central Statistical Bureau (Personal communication, 16 January 1997) office, however, failed to confirm telephonically an excess of live female births over that of male births. (This data is shown in the top row of the Table 6.1 above.) However, a contributory factor that might cause dropout and non-registration at school for boys is conceivably the national disillusionment with education and the low prospects of schooling being a route to work.

Table 6.2 Gender/age distribution - Lower Grade showing the excess numbers of girls over boys - South African data

← Excess of girls over boys (Percentages) | Excess of Boys over Girls → (Percentages)

5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5	Year of Birth	0.5	1.0	1.5
											1971			0.02%
											1972			0.02%
									0.02%		1973			
									0.01%		1974			
											1975			0.19%
											1976			0.42%
											1977			0.64%
											1978			0.76%
											1979			1.39%
											1980			1.06%
0.43%											1981			
5.01%											1982			
5.45%											1983			
1.02%											1984			
0.06%											1985			

↑ Excess percentage of Girls over boys | Excess percentages of Boys over girls ↑

Table 6.2 shows that within the sample consisting of 53.1 per cent to 45.9 per cent proportion of girls to boys, the trend is for the girls in the Lower Grade (Standard 5) to be appreciably younger than the boys.

Table 6.3, below, shows the same age/gender distribution for the Upper Grade students. Again the overall majority of younger girls over the relatively older boys is again clearly apparent.

The disparity in ages, illustrated below, as with that of gender, can perhaps be attributed to the political and social activities in the years immediately preceding 1995. 1982/3 were the birth years of the intended TIMSS sample group yet, in terms of numbers, only 51.23 per cent of the sampled group were in their thirteenth year or younger at the time of testing.

Table 6.3 Gender/age distribution - Upper Grade showing the excess numbers of girls over boys - South African data

Excess of girls over boys (Percentages) ← | Excess of Boys over Girls → (Percentages)

5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5	Year of Birth	0.5	1.0	1.5
0.05%											1970			
0.02%											1971			
											1972			
0.0											1973			0.09
0.07%											1974			0.0
											1975			0.52%
											1976			0.23%
											1977			1.68%
											1978			0.69 %
											1979			1.27%
1.36%											1980			
3.17%											1981			
3.42%											1982			
0.39%											1983			
0.05%											1984			
0.01											1985			

↑ Excess percentage of Girls over boys | Excess percentages of Boys over girls ↑

The original estimate made in 1993 of thirteen year old students that would be in the sample was 47.8 per cent. If the number of students twelve years and younger and those fourteen years and older are subtracted from the total number of students the proportion of thirteen year old students in the sampled group is 48.9 per cent. This provides confirmation that the pre-TIMSS estimates of the proportion of thirteen year old students in the sample population were in an acceptable range of accuracy (error 1.1%).

An almost uniquely South African finding was that it appeared that many of the responding students provided a year of birth but no month or day for the age information requested in the questionnaire. As shown earlier in Tables 5.5 - 5.8, only Colombia has an older average age than South Africa for the Upper and Lower Grade groups. The reasons for this sample being 'over age' are numerous and include late start to schooling, irregular schooling (dropping out for a year or more) and the frequency of students repeating a school year, particularly in Standard 6 [TIMSS

Upper Grade]. The distribution of ages in the Lower Grade is shown in Table 6.4 below.

Table 6.4 Age distribution as indicated by the South African sample group - Lower Grade (Standard 5)

(Average age of sample = 13.8 years (n = 5 287))

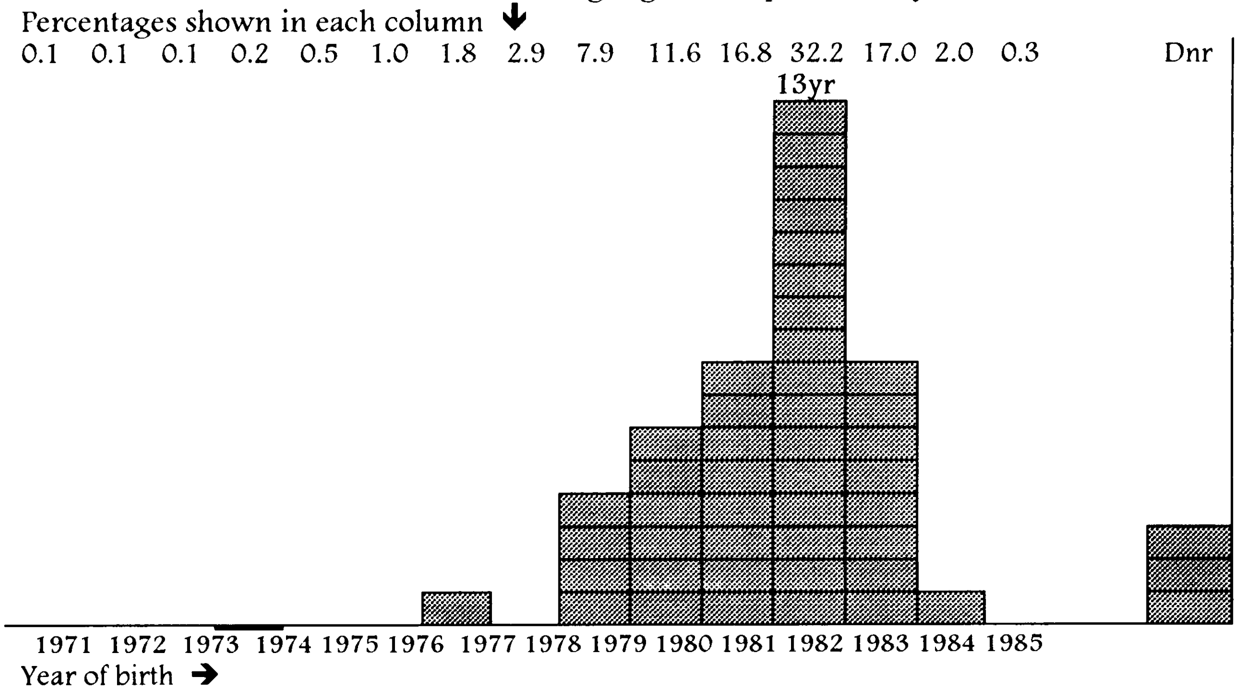
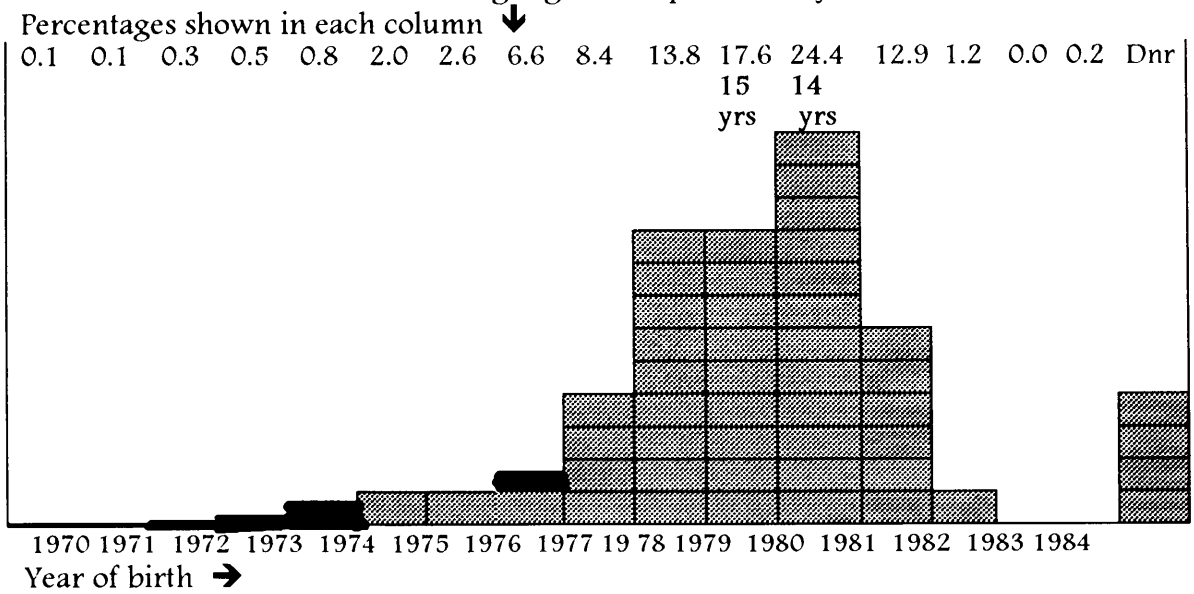


Table 6.5 Age distribution as indicated by the sample group - Upper Grade (Standard 6) - South African data

(Average age of sample = 15.3 years (n = 4 532))



6.3 HOME BACKGROUND

6.3.1 IMMIGRANT COMPONENT OF THE SAMPLE

Whilst it has been claimed in the Press (*Pretoria News*, 1996: 9) quoting government statements that, concurrent with the brain drain, there is also a serious influx of legal and illegal immigrants from neighbouring countries into South Africa, the proportion of the sample for Population 2 does not indicate such an anomalous population component.

In the Upper Grade, 5.1 per cent of the students admitted to being expatriates. In the Lower Grade, this percentage was 3.9 per cent. For both groups approximately 2.5 per cent of the sample failed to respond to this question, which could account for the lack of evidence of a problematic population in the questionnaire responses.

Anderson (Bachman, 1990: 324) makes the following observation concerning the testing situation or any controlled situation requiring responses:

> A test and a testing situation [such as the period of the controlled time allocated to the TIMSS questionnaire] is an Activity Type in its own right - it has its own defining characteristics, its own rules and purposes. The purposes of the participants in this Activity Type have their own "validity", their own authenticity.

From the above extract it is apparent that the 'testing' situation varies from time to time and from individual to individual depending on the particular situation. For example, countries such as Hong Kong (14 per cent), Australia (10.3 per cent) and New Zealand (12.4 per cent) show much higher figures for immigrants in their Population 2 returns. It is possible that, in the socio-political climate of 1995 South Africa, the 'agendas' of the respondents (that is, not to disclose their expatriate status) do not necessarily coincide with the agenda of the questionnaire.

The period of residence in South Africa shows a median value of thirteen years of residence. Less than 2 per cent of the total sample indicated arrival in South Africa in the past two years.

6.3.2 PARENTS OF THE SAMPLED GROUP

6.3.2.1 Proportion of parents not born in South Africa

The findings of the question concerning the country of birth of the parents reveal a reasonable consistence of responses between the two grades, with the exception that a much larger proportion of the Lower Grade students (8.9 per cent) failed to respond to the question of where their mothers were born.

These figures reveal that approximately 90 per cent of mothers (Lower Grade 91.5 per cent and Upper Grade 91.2 per cent) were South African born and a similar proportion of fathers were South African born (Lower Grade 89.1 per cent and Upper Grade 89.0 per cent). In the context of current South African immigration authorities organizing 'sweeps' to pick up illegal immigrants, again it is possible that 'incorrect' answers were given to hide parents' origins. Another possibility is that the students may not have been certain where they or their parents were born.

6.3.2.2 Education of parents

The tables below show a profile of education typical of developing countries, particularly in view of the fact that, due to a management oversight in the South African TIMSS office, there was no possible response for no education at all or for partial primary school education. If a substantial proportion of the 'did not respond' answers are taken as no education or as partial primary education, the picture becomes clearer and perhaps more typical of third world situation.

Table 6.6 Level of education of mothers of the sample group - South African data

LEVEL ↓	Percentage →	5 10 15 20 25 30 35	%
Primary School	UG		13.6
	LG		11.7
Part of Secondary School	UG		12.0
	LG		12.0
Complete Secondary School	UG		10.5
	LG		11.4
Vocational/Technical	UG		6.5
	LG		7.5
Incomplete University	UG		7.4
	LG		8.2
Completed University	UG		13.0
	LG		15.1
Do not know	UG		20.2
	LG		23.3
Dnr	UG		16.7
Dnr	LG		10.7

Referring to Tables 6.6 above, and Table 6.7, below, it is only at the level of an incomplete university education that the level of education of fathers overtakes the level of mothers' education.

An examination of the data in both these tables (6.6 and 6.7) suggests that the percentage of students claiming that their parents have completed a university education may be somewhat optimistic as a reflection of the national profile. In addition, the proportion of students, whose parents appear to have dropped out of Secondary School before completing the twelfth year appears to be somewhat low in terms of the Education and Manpower Development report (RIEP, 1994). This report shows a substantial drop of registered school students between Standard 9 and Standard 10. This report also provides no information of the numbers of repeaters in Standard 10.

It is striking that over 35 per cent of students in the combined participating grade populations failed to respond to this question or did not know the education levels of their parents. This may in part be due to the fact that the questionnaire had no place to indicate that parents had either received no formal education or that they had failed to finish primary school. Successive years of the RIEP manpower reports indicate a sharp drop out rate between each of the grades in primary and secondary schools. The Grade 1 to Grade 2 dropout rate is particularly high in most provinces and this is not reflected in the data as it was collected.

Table 6.7 Level of education of fathers of the sample group - South African data

LEVEL ↓	Percentage →	5 10 15 20 25 30 35	%
Primary School	UG		7.6
	LG		7.5
Part of Secondary School	UG		9.5
	LG		9.3
Complete Secondary School	UG		8.8
	LG		9.7
Vocational/Technical	UG		7.8
	LG		8.9
Incomplete University	UG		7.7
	LG		8.0
Completed University	UG		13.9
	LG		16.8
Do not know	UG		20.2
	LG		23.3
Dnr	UG		21.3
Dnr	LG		14.7

Table 6.8 Comparative education levels of parents between South African and other selected countries.

COUNTRY	MOTHERS			FATHERS		
	Less tha completed Sec.School	Complete Sec.School	All or Part Tertiary	Less than completed Sec. School	Complete Sec. School	All or Part Tertiary
South Africa	14.6%	10.7%	20.8%	17.1%	9.0%	23.1%
Iran	74.0%	8.3%	6.3%	66.4%	11.6%	14.2%
Colombia	50.7%	8.2%	24.4%	48.6%	8.8%	26.9%
Thailand	79.4%	4.3%	11.1%	70.2%	8.4%	14.9%
Czech Rep.	28.7%	35%	21.1%	30.6%	25.9%	24.0%
Australia	32.2%	19.8%	30.3%	26.2%	14.4%	38.4%
Belgium Fr.	10.5%	10.4%	79.0%	8.7%	9.0%	82.3%
Korea	36.1%	37.5%	17.0%	24.5%	36.7%	30.7%
Germany	42.3%	10.3%	19.9%	36.1%	10.5%	23.3%

Taking into account the fact that the parents of the Population 2 sample group were most likely being educated in the mid-1970s, the striking feature of this table is that South Africa does not stand out as having a particularly poorly educated population in terms of partially completed and completed schooling and tertiary education. Conversely, South African educationalists (Barry, 1996) refer to 30 per cent of the population as being functionally illiterate, but then, this enquiry into the education levels of a population neither sought to determine nor to describe the quality or relevance of the education provided and qualifications attained. The data above suggests that the proportion of South African parents who completed secondary school appears to be comparable to those of the other developing countries, and on a par with other national participants in TIMSS, despite the fact that countries like Colombia have invested heavily in technical and vocational education during the same period. The mid-1970s in South Africa saw the height of apartheid and its impact on education whilst in what was Czechoslovakia was experiencing the years of oppressive communism which immediately followed the 'Dubcêk' uprising in 1968. With the exception that more

Czechoslovakian parents (mothers and fathers) than South African parents appear to have completed secondary school, the education level of students' parents in these two countries appears to be comparable with the exception that there is no South African data for parents with no education or with a partial primary school education. The present-day achievements of their children, however, are not in any way comparable. Reasons for this discrepancy in achievement could be attributed to many factors including a national Czech 'culture of learning', the South African political policy of the pre-democracy period of 'revolution before education' and the substantially better educational resources and environment of the Czech Republic.

6.3.3 PEOPLE LIVING IN THE HOME

6.3.3.1 Number of people living in the home

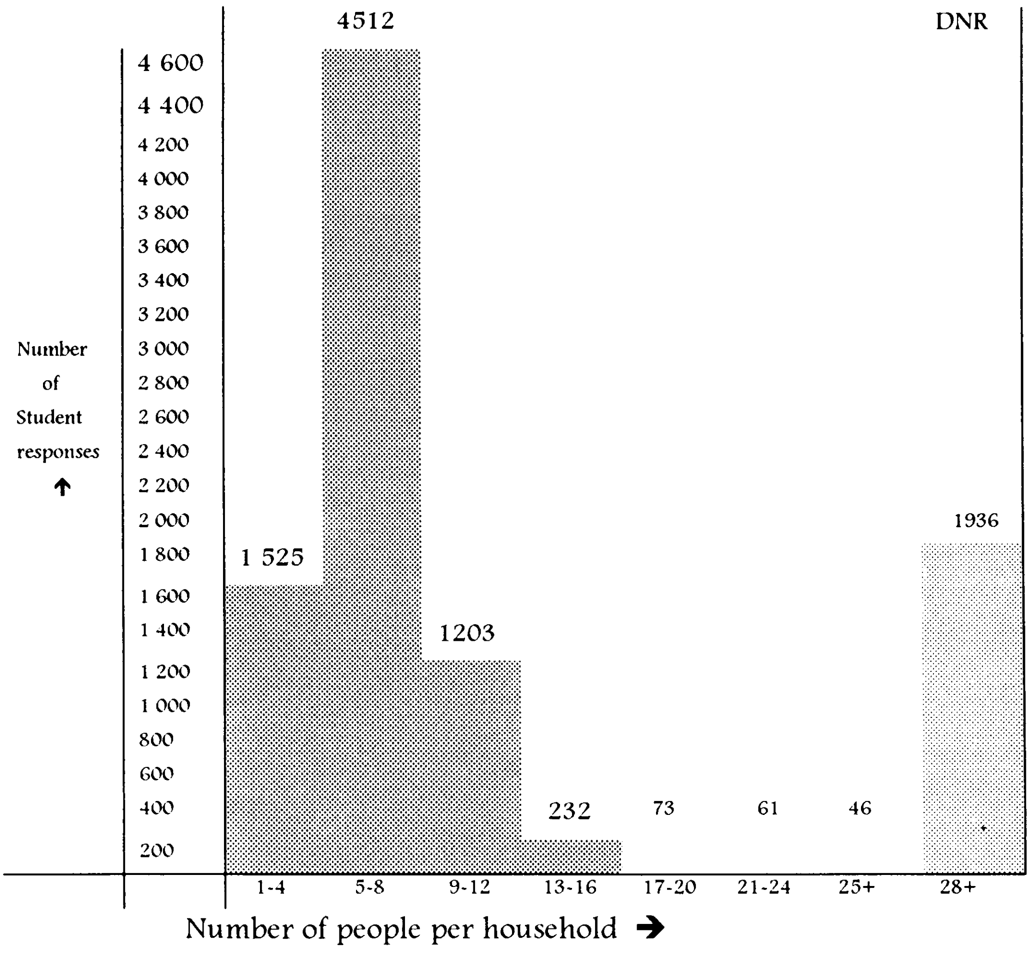
Table 6.9 presents information for both the Lower and the Upper Grades for the number of residents in the students home. It can be assumed that those students living in exceptionally large households are either living in extended family/clan homes or in hostel accommodation. These findings may be typical of developing countries in terms of large families and high density living conditions. For example, Colombia has a mean number of 6.6 people living in the home, Iran 7.2 people, and Thailand 5.5 people. The lower ranges of average inhabitants in the home are: Belgium (Fr) 4.3, and the majority of Northern Hemisphere countries range from 4.4 to 4.8 people per home. However, there appears to be some discrepancy in the reliability of the responses in that further on in the questionnaire (Table 6.25) 57.7 per cent of students in both grades indicate that they have a room of their own. If the reliability of the percentages obtained is accepted, it would be indicative of substantial dwellings which cannot be verified on a national basis. This raises the question of the validity of this item, where validity is perceived (Messick in Bachman, 1990: 236) as:

> An integrated evaluative judgement of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences and actions based on test scores [or, by extension, on questionnaire returns].

And, as Ebel (1972: 442) cautions:

> There is no simple, uniform, wholly objective procedure for determining the validity of a test or a test item [or a questionnaire response].

Table 6.9 The population per household - South African data for the Lower and Upper Grades



International returns on the population of households reveals that only Kuwait shows a higher value at 11.4 people per household than the South African average of just under eight persons. Colombia (6.6), as mentioned above, and Mexico (6.8) show average household populations to be over six. Japan, which might have made an interesting comparison - given the high population density - did not provide data for this question.

6.3.3.2 Relationship of occupants of the home to the sample group

Obtaining and representing this type of family data in societies where polygamy, extended families and Common Law households are the norm rather than the exception becomes difficult, more so when attempting to represent this data in a comparative international context. To avoid complications that would yield relatively little informative data, TIMSS - South Africa decided not to modify this question for the purposes of the international data set fit.

The relatively low percentage of South African fathers living in the home (less than 55 per cent) is much lower than that shown by other participating countries. This may, in part, be explained by the phenomenon of migrant labour in South Africa where the man works in a city or on a mine and maintains a rural home and family. Only Colombia (69.5 per cent) shows absentee fathers to be nearly as common as in South Africa. This situation is compounded by cases where the father has abandoned the family.

All participating countries, except Romania (82.6 per cent) and South Africa (82.6 per cent), indicate that over 93 per cent of mothers live in the same home as the students. Absentee fathers, on the other hand, are fairly common as argued above. Contrary to expectations, the international data suggests that there may be a relationship between 'fathers in the home' and achievement but the correlation is low.

With further reference to Table 6.10, below, no country shows a similar level of three generation households as South Africa (the percentage of grandparents living in the home is 43). The Western European countries all show returns of less than 7 per cent of students who have grandparents living in the same household as the student. Statistics from other developing countries, however, show that Iran (18.6 per cent), Colombia (31.1 per cent) and Thailand (34.4 per cent) have among the higher proportions of three generation households, but none of these countries comes close to the South African figure.

Table 6.10 Relationship of occupants living in the same home as the students in the sample group - Lower and Upper Grade - South African data

	0% 10 20 30 40 50 60 70 80 90 100	Dnr %
Mother	82.6	4.8
Father	53.8	10.4
Stepfather	12.4	16.4
Stepmother	8.3	16.2
Brothers	59.8	7.8
Sisters	57.8	13.0
Grandparents	43.1	14.8
Other family members	44.3	13.9
Non-related	28.2	15.2

(Dnr = Did not respond)

With the exception of Colombia (24.1 per cent), and the Slovak Republic(33.0 per cent) less than 15 per cent of Population 2 student homes have non-relatives living with them. Extended families made up of other family members living the same house are characteristic of the developing nations and of the former Eastern European nations.

6.3.4 USE OF LANGUAGES AT HOME

In view of the earlier discussion of language and language problems in Mathematics and Science education (see 2.2.1 - 2.2.5) the use of languages in the home is of particular interest.

In the Population 2 sample, just over one fifth (21.4 per cent) of the students claim that they use English or Afrikaans as the dominant home language whilst another 58.5 per cent claim that these languages are used occasionally. The balance of 20.1 per cent claim never to use either of the languages at home.

Question 4 of the students' questionnaire enquired into the language the students used in their homes. In terms of achievements, this question assumes considerable importance when interpreting the South African findings and so the relationship between mother tongue usage, language of instruction and achievement is discussed in some depth in the following paragraphs (6.4 ff.). Table 6.11 provides a national view of the responses to the question on the use of language of instruction in the home:

Table 6.11 Language of testing and the home language of respondents - South African data

Province	Use of Language of testing in the home: Always/Frequently	Seldom	Never
NATIONAL	1 985	5427	1864
	21.4%	58.5%	20.1%

Only Hong Kong (which reports that 31.4 per cent of the students never use the language of testing at home) exceeds the proportion of South Africans (20.1 per cent) who claim never to use the language of testing as their home language. It should be noted though, that the NRC for Hong Kong also indicated that this country provided bilingual (English and Cantonese) test papers to all schools irrespective of the medium of instruction. South African students only received test papers and questionnaires in the language of instruction, that is in English or in Afrikaans but not both languages. Although the standard of language (English or Afrikaans) used by second language speakers at home may not be very high, as shown in columns 2 and 3 in Table 6.11, above, the TIMSS findings suggest that these languages may not be as 'foreign' as may have been thought (see 2.2.1 - 2.2.3). Nevertheless, it is apparent from the South African data that language could have been an impediment to higher achievement.

6.4 THE LANGUAGE OF INSTRUCTION, LITERACY AND ACHIEVEMENT

6.4.1 THE RELEVANCE OF THE IEA STUDY ON READING AND LITERACY

Elley's (1992) report on the earlier IEA study on reading and literacy contributes substantially to the background of the findings in the recent TIMSS study (1995) as it reflects on the South African findings. Elley's summary (i - xi) lists a number of relevant findings from which still valid deductions, applicable to TIMSS - South Africa, can be made:

- There is a strong correlation between literacy and achievement. It appears that national achievement levels in the IEA literacy tests relate to achievement in TIMSS but the correlation is by no means straightforward. Factors such as the mother tongue and second language instruction are a consideration (besides South Africa, Hong Kong and Singapore are examples of countries that face this problem as indicated above).

- The recognition level of a language (the level of the relationship - complex, in the case of English, or simple, as in the case of Finnish - between the symbolic appearance of the language and its phonic relationships) is a factor influencing achievement. This difficult recognition level in the case of English amplifies the problems for just under 80 per cent of the South African sample. On the other hand Afrikaans has a very high level of recognition.
- Social and cultural domain profiles also play a major part in the decoding of words and sentences to a comprehension level. Countries tend to show particular skills, aptitudes or preferences in language such as narrative abilities (in the case of Greece and Cyprus), or 'document' comprehension skills, that is, comprehension of written passages (in the case of Hong Kong and Germany, for example). The third field of the IEA literacy investigation, the expository mode, is of less interest and relevance to Mathematics and Science achievement.
- Economic and social contexts impinge on literacy which in turn have an effect on Mathematics and Science achievement. High economic status appears create an environment in which reading skills are developed and hence higher achievement follows. This relationship between economic status and achievement was discussed in 1.4.2.3 of this thesis. High literacy levels also appear to impact beneficially on the understanding of Mathematics and Science and to modify the concepts of 'street science' referred to by Thijs and van den Berg (1995: 317-347).
- Instruction in a language other than the home language or mother tongue in specific countries (for example, Singapore and Hong Kong) appears to exert no detrimental effect on achievement. Elley makes the

point though (*ibid.* xi) that the level of negative impact relates very closely to the language mastery of the teachers themselves. It is possible, therefore, to attribute the negative effect of the language of instruction on achievement to factors other than the student's own second language problems. In South Africa, for example, one of the key factors appears to be this lack of language mastery by the teachers themselves (see also Odendaal, 1985). In consequence, an additional factor in the interpretation of the TIMSS findings - represented in both statistical and graphic form later in this chapter - is thus the way in which the results of those schools with teachers, who are proficient in the language of instruction, as well as students, whose mother tongue corresponds with the language of instruction, tend to skew the macro-view obtained from the statistical analysis.

- The last significant point that Elley makes that clarifies part of the TIMSS findings is that literacy levels correlate highly with school reading resources, as opposed to home reading resources, and the importance that teachers place on reading. The intellectual distinction between decoding and comprehending text, so essential in the formation of clear concepts is dealt with in 7.3.6. South African students are, by and large, severely disadvantaged when it comes to reading (library) resources in their schools.

6.4.2 AN ANALYSIS OF ACHIEVEMENT AND THE LANGUAGE OF INSTRUCTION THAT STUDENTS USE AT HOME

In an analysis of TIMSS - South Africa, Elley's findings appear to have validity in statistical terms. Statistical analysis of the relationships between achievement and mother tongue and language of instruction is a key issue in South African education and therefore merits deeper investigation.

In the questionnaire which, like the TIMSS achievement tests themselves, was presented in both English and Afrikaans, the students were asked to respond to the following key (in the context of this discussion) question:

> How often do you speak English (or Afrikaans) at home?
>
> *Circle either A, B or C.*
>
> | | |
> |---|---|
> | Always or almost always | A |
> | Sometimes | B |
> | Never | C |

6.4.3 DUNCAN'S MULTIPLE RANGE TEST

This method compares the error rate for each pairwise comparison (rather than the overall rate) and allows a higher rate for pairs of simple averages. The SAS Programme printout displays different symbols [A, B, and C] where there are significant differences. Where there is no significant difference at the 5% level the symbols are the same [BB or AA] (Dowdey & Wearden, 1983: 262-271).

NOTE 1: The Northern Cape Province data has been omitted on the grounds that the sample of schools (2) in this province was too small to permit significance of variance calculations.

NOTE 2: In the cases where the number of students is very small or very different in size, significance of variation calculation loses some validity.

NOTE 3: All the scores in the tables that follow are represented on a full scale value of 800, a mean of 500 and a standard deviation of 100.

Table 6.12 Significance of variance between mean scores of students' answers to home language and language of instruction [LG]

(a) Standard 5- Mathematics. Always/Frequently (A) vs. Occasionally(B)

Province	Mean A	Mean B	n A	n B	Significant difference at the 5% level	Duncan Significance
Province 01	377.97	340.47	54	337	Significant	A B
Province 02	345.20	335.18	81	73	Significant	A B
Province 03	404.14	335.18	148	495	Significant	A B
Province 04	394.92	343.48	298	758	Significant	A B
Province 05	378.67	325.12	90	241	Significant	A B
Province 06						-
Province 07	334.81	325.23	142	479	Significant	A B
Province 08	415.13	338.68	108	322	Significant	A B
Province 09	360.54	356.96	203	90	Not significant	A A
National	378.57	335.59	1124	2899	Significant	A B

(n = number of respondents)

(b) Standard 5 - Mathematics. Occasionally (B) vs. Never (C)

Province	Mean B	Mean C	n B	n C	Significant difference at the 5% level	Duncan Significance
Province 01	340.47	327.87	337	107	Not significant	B B
Province 02	323.95	321.04	73	177	Not significant	B B
Province 03	335.18	322.00	495	94	Significant	B C
Province 04	343.48	334.46	758	166	Not Significant	B B
Province 05	325.12	317.78	241	97	Not significant	B B
Province 06						-
Province 07	325.23	330.26	479	381	Not significant	B B
Province 08	338.68	335.99	322	103	Not significant	B B
Province 09	356.96	334.80	90	2	Not significant	A A
National	335.69	328.88	2899	1123	Significant	B C

(c) Standard 5 - Mathematics. Always/Frequently (A) vs. Never (C)

Province	Mean A	Mean C	n A	n C	Significant difference at the 5% level	Duncan Significance
Province 01	377.97	327.87	54	107	Significant	A B
Province 02	345.20	321.04	81	177	Significant	A B
Province 03	404.14	322.00	148	94	Significant	A C
Province 04	394.92	334.46	298	166	Significant	A B
Province 05	378.67	317.78	90	97	Significant	A B
Province 06						-
Province 07	334.81	330.26	142	381	Significant	A B
Province 08	415.13	335.99	108	103	Significant	A B
Province 09	360.54	334.80	203	2	Not significant	A A
National	378.57	328.88	1124	1123	Significant	A C

Table 6.13 Significance of variance between mean scores and students' answers to home language and language of instruction [UG]

(a) Standard 6 - Mathematics. Always/Frequently (A) vs. Occasionally (B)

Province	Mean A	Mean B	n A	n B	Significant difference at the 5% level	Duncan Significance
Province 01	392.33	338.51	55	362	Significant	A B
Province 02	405.88	337.0	135	258	Significant	A B
Province 03	424.01	336.63	151	493	Significant	A B
Province 04	367.50	333.76	183	450	Significant	A B
Province 05	396.74	332.63	66	276	Significant	A B
Province 06						-
Province 07	342.94	336.16	106	344	Not significant	A A
Province 08	354.83	347.33	21	397	Not significant	A A
Province 09	401.57	460.10	75	9	Significant	B A
National	388.58	338.05	792	1123	Significant	A B

(b) Standard 6 - Mathematics. Occasionally (B) vs. Never (C)

Province	Mean B	Mean C	n B	n C	Significant difference at the 5% level	Duncan Significance
Province 01	338.51	323.99	362	118	Not significant	B B
Province 02	337.40	323.78	258	53	Not significant	B B
Province 03	336.63	340.25	493	60	Not significant	B B
Province 04	333.76	326.67	450	164	Not significant	B B
Province 05	332.63	334.51	276	90	Not significant	B B
Province 06						-
Province 07	336.16	329.71	344	292	Not significant	B B
Province 08	347.33	351.57	90	2	Not significant	A A
Province 09	460.10	-	9	2	-	-
National	338.05	331.16	2589	853	Significant	B C

(c) Standard 6 - Mathematics Always/ (A) vs. Never (C)

Province	Mean A	Mean C	n A	n C	Significant difference at the 5% level	Duncan Significance
Province 01	392.33	323.99	362	118	Significant	A B
Province 02	405.88	323.78	258	53	Significant	A B
Province 03	424.01	340.25	493	60	Significant	A B
Province 04	367.50	326.67	450	164	Significant	A B
Province 05	396.74	334.51	276	90	Significant	A B
Province 06						-
Province 07	342.94	329.71	344	292	Significant	A B
Province 08	354.83	351.57	397	76	Not significant	A A
Province 09	401.57	-	9	2	-	-
National	388.58	331.16	2589	853	Significant	B C

Table 6.14 Significance of variance between mean scores and students' answers to home language and language of instruction [LG]

(a) Standard 5 - Science. Always/Frequently (A) vs. Occasionally (B)

Province	Mean A	Mean B	n A	n B	Significant difference at the 5% level	Duncan Significance
Province 01	350.05	304.76	54	337	Significant	A B
Province 02	317.63	268.79	81	177	Significant	A B
Province 03	394.46	296.70	148	495	Significant	A B
Province 04	385.80	312.17	298	758	Significant	A B
Province 05	383.97	284.71	90	241	Significant	A B
Province 06						-
Province 07	296.42	284.63	142	479	Not significant	A A
Province 08	405.58	310.13	108	322	Significant	A B
Province 09	356.70	338.09	203	90	Not significant	A A
National	365.55	299.75	1124	2899	Significant	A B

(b) Standard 5 - Science. Occasionally (B) vs. Never (C)

Province	Mean B	Mean C	n B	n C	Significant difference at the 5% level	Duncan Significance
Province 01	304.76	279.89	337	107	Significant	B C
Province 02	268.79	268.60	177	73	Not significant	B B
Province 03	296.70	290.54	495	94	Not significant	B B
Province 04	312.17	287.26	758	166	Significant	B C
Province 05	284.71	282.89	241	97	Not significant	B B
Province 06						-
Province 07	284.63	284.84	479	381	Not significant	A A
Province 08	310.03	302.23	322	103	Not significant	B B
Province 09	338.09	318.70	90	2	Not significant	A A
National	299.75	285.71	2899	1023	Significant	B C

(c) Standard 5 - Science. Always/Frequently (A) vs. Never (C)

Province	Mean A	Mean C	n A	n C	Significant difference at the 5% level	Duncan Significance
Province 01	350.05	279.89	54	107	Significant	A C
Province 02	317.63	268.60	81	73	Not Significant	B B
Province 03	394.76	290.54	148	94	Significant	A B
Province 04	385.80	287.26	298	166	Significant	A C
Province 05	383.97	282.89	90	97	Significant	A B
Province 06						-
Province 07	296.42	284.84	142	381	Not significant	A A
Province 08	405.58	302.23	108	103	Significant	A B
Province 09	356.70	318.70	203	2	Not significant	A A
National	365.55	285.71	1124	1023	Significant	A C

Table 6.15 Significance of variance between mean scores and students' answers to home language and language of instruction [UG]

(a) Standard 6 - Science. Always/Frequently (A) vs. Occasionally (B)

Province	Mean A	Mean B	n A	n B	Significant difference at the 5% level	Duncan Significance
Province 01	373.44	301.25	55	362	Significant	A B
Province 02	417.84	288.54	135	258	Significant	A B
Province 03	426.85	305.93	151	493	Significant	A B
Province 04	360.33	295.15	183	450	Significant	A B
Province 05	358.89	289.32	66	276	Significant	A B
Province 06						-
Province 07	306.71	280.73	106	344	Significant	A B
Province 08	336.50	324.84	21	397	Not significant	A A
Province 09	422.67	470.41	75	9	Not Significant	A A
National	381.70	300.02	792	2589	Significant	A B

(b) Standard 6 - Science. Occasionally (B) vs. Never (C)

Province	Mean B	Mean C	n B	n C	Significant difference at the 5% level	Duncan Significance
Province 01	301.25	296.27	362	118	Not significant	B B
Province 02	288.54	277.23	258	53	Not Significant	B B
Province 03	305.93	297.64	493	60	Not significant	B B
Province 04	295.15	283.85	450	164	Not significant	B B
Province 05	289.32	285.27	276	90	Not significant	B B
Province 06						-
Province 07	280.73	274.94	344	292	Not significant	B B
Province 08	324.84	308.01	397	76	Not significant	A A
Province 09	470.41		9			
National	300.02	285.39	2589	853	Significant	B A

(c) Standard 6 - Science. Always/Frequently (A) vs. Never (C)

Province	Mean A	Mean C	n A	n C	Significant difference at the 5% level	Duncan Significance
Province 01	373.44	296.27	55	118	Significant	A B
Province 02	417.84	277.33	135	53	Significant	A B
Province 03	426.85	297.64	151	60	Significant	A B
Province 04	360.33	283.85	183	164	Significant	A B
Province 05	358.89	285.27	66	90	Significant	A B
Province 06						-
Province 07	306.71	274.94	106	292	Significant	A B
Province 08	336.50	308.01	21	76	Not significant	A A
Province 09	422.67		75	2		
National	381.70	285.39	792	853	Significant	A C

The significance of variances between means can be summarized as follows:

- The differences in achievement between those students who occasionally speak the language of instruction at home and those who never speak this language at home is both slight and infrequent in some provinces.
- It appears that there is a consistent (with the exception of Province 09) significance, at the 5% level, between the achievement of students who use the language of instruction always or frequently at home and those who seldom or never speak the language of instruction at home.
- The significance of each pair of means appear to be more apparent in the Science test results than in the Mathematics test results. This is possibly due to the larger and more specialized lexicon expected by the sciences.
- It is notable that the Science scores for four provinces, for the students that spoke the language of instruction at home, frequently or always, totalled scores over that of Colombia at the Upper Grade. In the case of Mathematics the same group of students achieved scores higher than those of Colombia and Kuwait at the Upper Grade.

6.4.4 A MESO-ANALYSIS OF THE EFFECT OF LANGUAGE OF INSTRUCTION ON ACHIEVEMENT

Duncan's statistical analysis of the significance of variance deals with the 'macro-features' of the populations trends. On the other hand, a graphic display of achievement scores (see the tables that follow) of the three respondent groups suggests, at the meso-level, that for the broad middle band of performances there is so much overlap between the groups as to imply that the language of instruction problem may exert less impact on achievement than has been thought. There are few schools or provinces which show a clear advantage in achievement of the 'Always/Frequently' respondents over the other two groups. Those students who claim never to speak the language of instruction at home do not consistently provide the lowest scores, nor does the 'Always/Frequently' group provide the highest scoring students. The majority of students answering Always/frequently to the home language question record achievements that lie within the main band of achievement. Four of these micro-analyses (Tables 6.16 - 6.19) follow. (Additional provincial analyses of achievement and home language usage is attached are Appendix 5.)

It appears that, as already argued, whilst language of instruction has attracted considerable research attention, the frequency of low scores by these respondents, who claim to use the language of instruction in their homes 'Always/Frequently', is not wholly attributable to language of instruction. Other causes for the low South African scores must be considered among which are the level of language proficiency of teachers, the availability of books (discussed earlier), and, perhaps even more significant, the 'time on task' problem (discussed in Chapter 7). Thijs and van den Berg (1995: 333) assert that didactic style strongly influences the ability of students to form 'correct' concepts. The 'teacher transmits and the student receives' style of teaching, so general in South Africa (see the analysis of student questionnaires in 6.6.1), is not seen as an efficacious method for instilling correct mathematical and scientific concepts. Thijs and van den Berg emphazise that a discursive approach is far more effective both for learning and for the restructuring of misconcepts.

- In the graphs (see Tables 6.16 - 6.19 and Appendix 5)) it is evident that the highest scores are in Science as is the widest range of scores. School number 108 in Province 07, with only 2 students (out of 37 students) who speak the language of instruction at home, is one of the higher scoring schools in the national sample.

- It is also clear that the usual highest scores are achieved by those students who speak the language of instruction at home. The meso-analysis impression though is that apart from a very few outstanding (in terms of achievement) schools in each province, use of language of instruction in the home exerts a reduced 'school level' benefit to many of the students. Poor achievement can be achieved to other factors such as 'time on task', poorly qualified and motivated teachers and poor facilities in the schools.

By way of explanation of the graphs that follow (Tables 6.16 - 6.19):

- Each vertical column represents a single school with its TIMSS code shown along the horizontal axis.

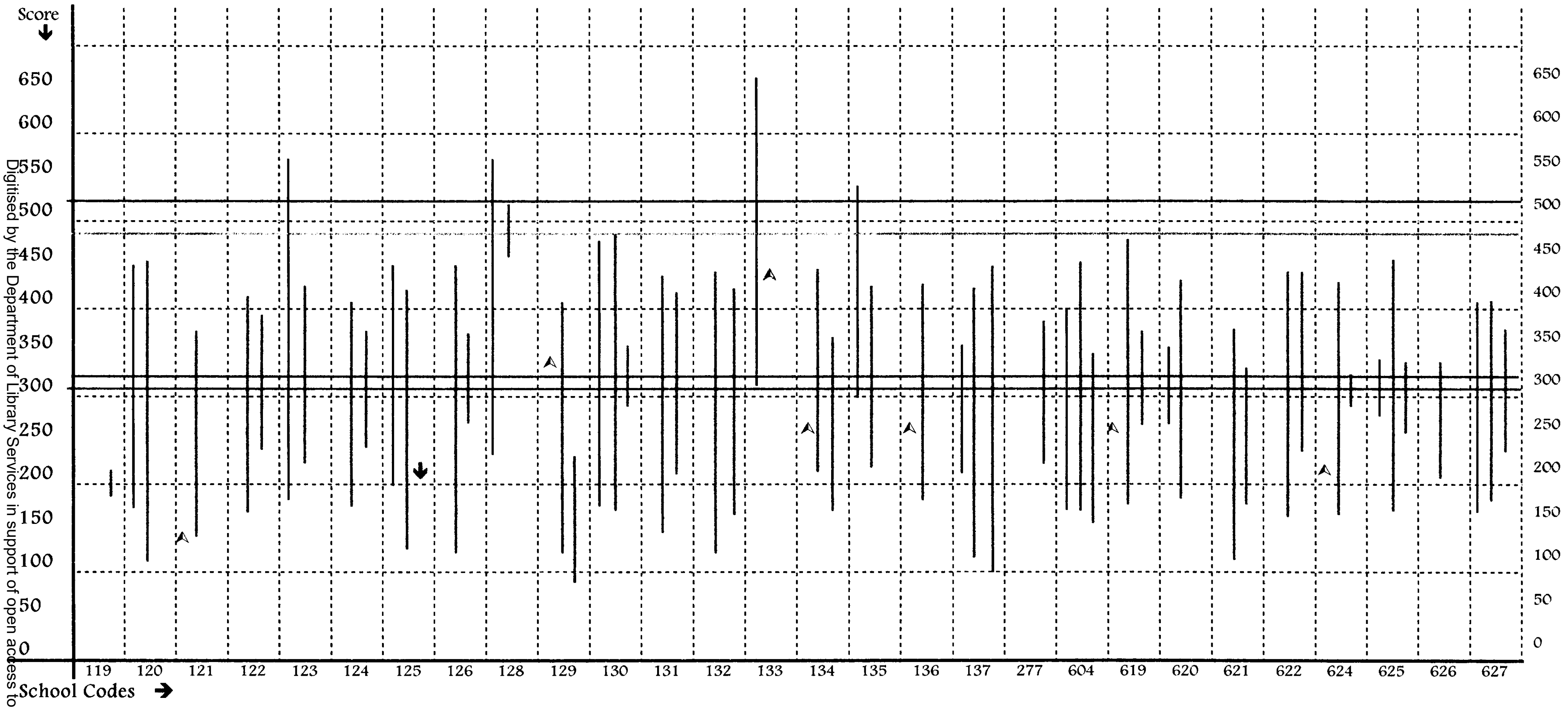
  Within each school column there may be up to three lines.

  ① the **black** line represents those students who indicated that they speak the language of testing 'always or frequently' at home,
  ② the **blue** line indicates those students who speak the language of testing at home 'occasionally' and,
  ③ the **red** line indicates those students who 'never' speak the language of testing at home.

- The length of the line indicates the range between the highest and the lowest scores in each responding group.

- The lines do not indicate the number of respondents in each group or in each school.

Table 6.16 Province 03 - Science (I) - Range of marks for each language response

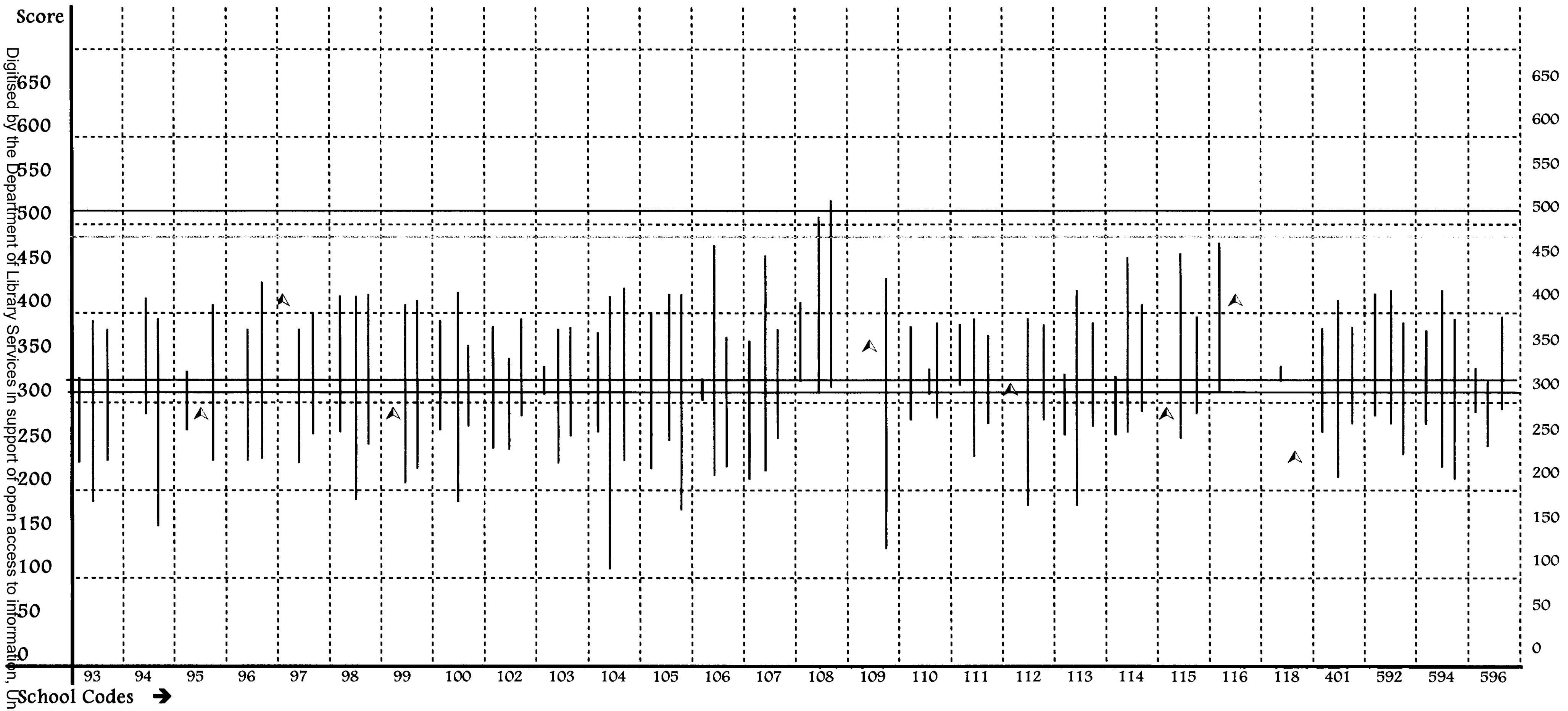


KEY:

Always/Frequently —— Occasionally —— Never —— Single response ⅄ ⅄ ⅄

South African average UG —— LG —— International average UG —— LG ——

Table 6.19 Province 07 - Mathematics (I) - Range of marks for each language response



KEY:

Always/Frequently Occasionally Never Single response

South African average UG LG International average UG LG

Table 6.18 Province 07 - Science (I) - Range of marks for each language response

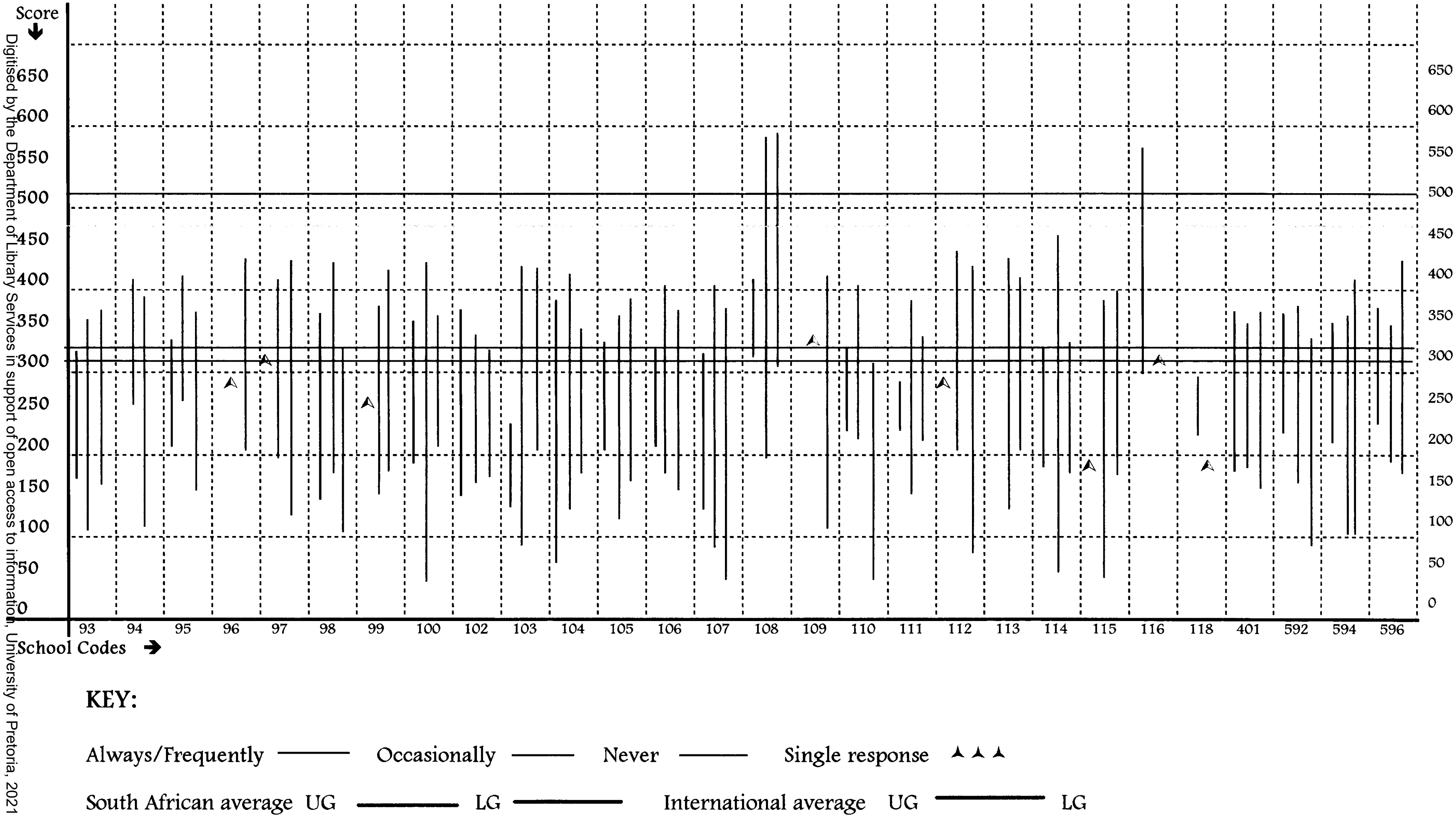
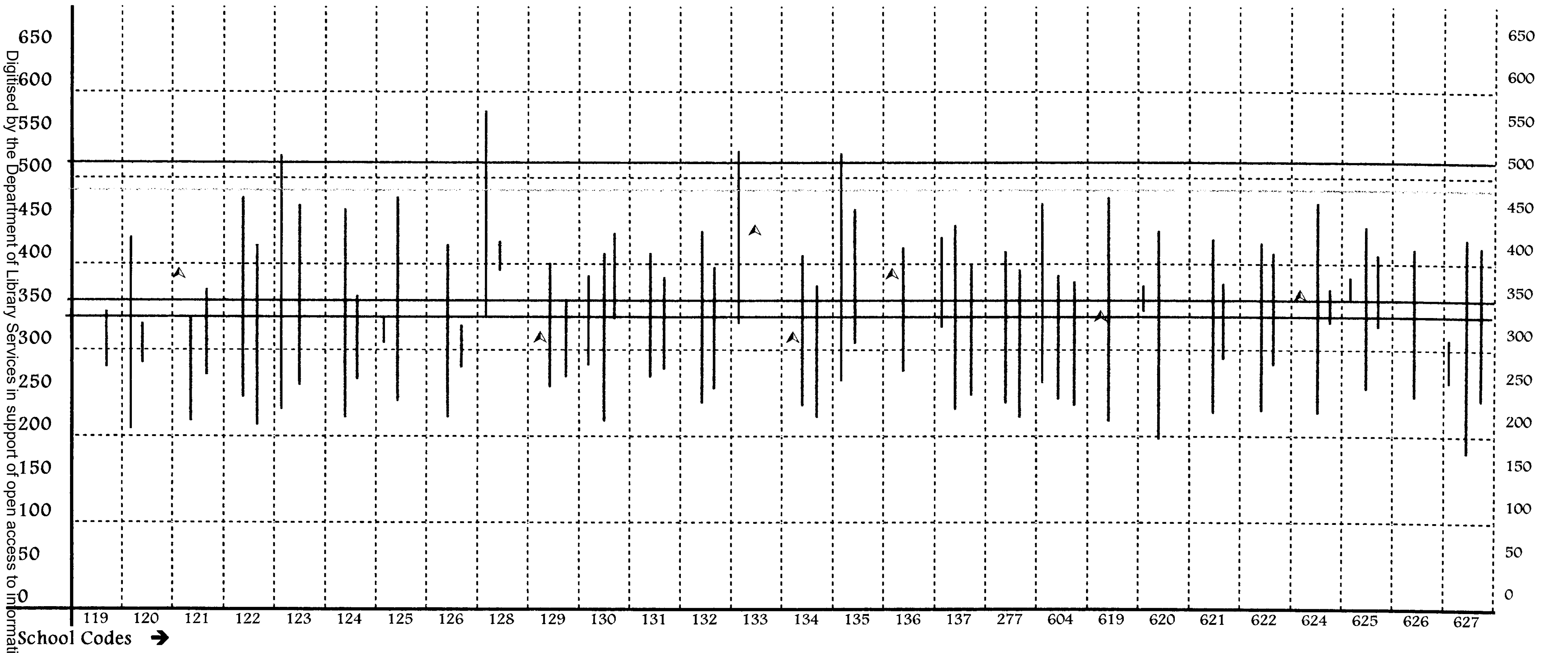


Table 6.17 Province 03 - Mathematics (I) - Range of marks for each language response



KEY:

Always/Frequently ——— Occasionally ——— Never ——— Single response

South African average UG ——— LG ——— International average UG ——— LG ———

It is clear that, whilst in a few schools, the students who claim to speak the language of testing at home always or frequently score the higher marks, overall the substantial overlap between the ranges of the three groups of language users is of itself a phenomenon of some significance.

6.5 BOOKS IN THE HOME

Although the Second International Mathematics and Science Study (see 1.1.2.3.[a], Research Finding 8) suggested strongly that the number of books in the students' homes relates directly to student achievement, the findings of the Third International Mathematics and Science Study suggest otherwise. The number of books in the home has been regarded as a measure of the literacy level of the home milieu and a factor influencing attitudes towards learning and the resources the student has as a learning support. This proposition is examined critically and is challenged in terms of the international data collected in the TIMSS student questionnaires.

Table 6.20 The number of books in the students' homes - Lower Grade and Upper Grade - South African data

Number of books	Upper Grade	Percentage	Lower Grade	Percentage	Percentage for both Grades
1 - 10	1 433	33.2	1 620	30.6	32.0
11 - 25	1 104	25.4	1 446	27.4	26.7
26 - 100	619	14.2	856	16.2	15.4
101 - 200	251	5.8	346	6.5	6.2
>200	452	10.4	595	11.3	11.0
Dnr	483	11.1	424	8.0	9.4

From the evidence above, it would appear that nearly 60 per cent (32.0% + 26.7%) of Population 2 students in South Africa have relatively few books to call upon in their homes as a support system to literacy and knowledge.

6.5.1 Books in the home - international comparison data

Table 6.21 Comparative international data on books in the home - Lower Grade - South African data

	South Africa	Colombia	Iran	Thailand	France	Australia	Canada	Japan
1-10	30.6	27.3	38.7	18.8	5.4	2.0	4.4	
11-25	27.4	32.7	33.3	30.1	19.9	6.0	10.5	
26-100	16.2	25.2	14.7	33.3	35.8	25.5	25.8	
101-200	6.5	8.9	5.0	9.5	18.1	25.0	23.8	
>200	11.3	5.9	8.3	8.4	20.8	41.5	35.5	
Dnr	8.0	2.6	3.4	1.7	4.4	3.3	1.7	100.0

Table 6.22 Comparative international data on books in the home - Upper Grade - South African data

	South Africa	Colombia	Iran	Thailand	France	Australia	Canada	Japan
1-10	33.2	25.6	37.3	18.6	5.4	3.1	4.2	-
11-25	25.4	31,5	32.1	30.2	17.1	6.8	10.1	-
26-100	14.2	26.6	17.0	33.4	36.4	23.5	28.1	-
101-200	5.8	9.0	6.4	9.0	21.1	24.7	24.8	-
>200	10.4	7.3	7.2	8.8	19.9	42.0	32.7	-
Dnr		2.3	2.3	1.3	5.1	3.8	2.8	100.0

(Japan submitted no returns for this question.)

6.5.2 The implications of student reports on books in their homes

A Rank order correlation between the percentage of homes with over one hundred books in the home and high achievement is informative.

Table 6.23 Spearman's Rank Order Correlation calculation: many books in the home (100+) vs. Rank Order of achievement.

NOTE:The source of the achievement data and the ranking order of books in the home - TIMSS p-value almanacs for student questionnaires (1996 (b-f)).

	ACHIEVEMENT RANK X	RANK MOST BOOKS IN HOME Y	X-Y	$(X-Y)^2$
1. Singapore	1	12	-11	121
2. Korea	2	4	-2	4
3. Hong Kong	3	32	-29	841
4. Belgium Fl.	4	30	-26	676

5 Czech Rep.	5	11	-6	36
6 Slovak Rep.	6	2	4	16
7 Slovenia	7	5	2	4
8 Switzerland	8	20	-12	144
9. Netherlands	9	13	-4	16
10. Bulgaria	10	1	9	81
11. Austria	11	31	-20	400
12. France	12	15	-3	9
13. Hungary	13	28	-15	225
14. Russia	14	6	8	64
15. Australia	15	24	-9	81
16. Ireland	16	14	2	4
17. Canada	17	8	9	81
18. Belgium Fr	18	11	7	49
19. Thailand	19	37	-18	324
20. Sweden	20	24	-4	16
21. Germany	21	25	-4	16
22. New Zealand	22	27	-5	25
23. England	23	21	2	4
24. Norway	24	22=	1	1
25. Denmark	25	17	8	64
26. United States	26	19	7	49
27. Scotland	27	22=	4	16
28. Latvia	28	33	-5	25
29. Spain	29	18	11	121
30. Iceland	30	9	21	441
31. Greece	31	7	24	576
32. Lithuania	32	16	16	256
33. Romania	33	35	2	4
34. Cyprus	34	10	24	576
35. Portugal	35	29	6	36
36. Iran	36	36	0	0
37. Colombia	37	34	3	9
38. South Africa	38	38	0	9
				Σ = 6 992

$$\rho = 1 - \frac{6 \Sigma D^2}{N(N^2 - 1)}$$

$$= 1 - \frac{6 \times 6992}{38(38^2 - 1)}$$

$$1 - \frac{41\ 952}{54\ 834}$$

$$= 1 - 0.765 = 0.24$$

Spearman's Rank Order correlation coefficient is a statistical process for determining the relationship between two variables. A correlation coefficient of 0 indicates no relationship, a correlation of 1 indicates a perfect direct relationship between two measures and a correlation of -1 indicates a perfect inverse relationship. As discussed more fully below, a correlation coefficient of 0.24 indicates that there is only a weak relationship existent between achievement and the number of books in the students' homes.

Table 6.24 Spearman's Rank Order Correlation calculation: few books in the home (<10) vs. Rank Order of achievement.

NOTE:The source of the achievement data and the ranking order of books in the home - TIMSS p-value almanacs for student questionnaires (1996 (b-f))

	ACHIEVEMENT RANK X	RANK LEAST BOOKS IN HOME Y	X-Y	$(X-Y)^2$
1. Singapore	37	10	27	729
2. Korea	36	13=	23	529
3. Hong Kong	35	5	30	900
4. Belgium Fl.	34	15	19	361
5. Czech Rep.	33	37	-4	16
6. Slovak Rep.	32	34	-2	4
7. Slovenia	31	30	1	1
8. Switzerland	30	22	8	64
9. Netherlands	29	16	13	169
10. Austria	28	9	19	361
11. France	27	23	5	25
12. Hungary	26	27	-1	1
13. Russia	25	21	4	16
14. Australia	24	33 =	-9	81
15. Ireland	23	14	10	100
16. Canada	22	25	-3	9
17. Belgium Fr	21	21=	0.5	0.25
18. Thailand	20	36	-16	256
19. Sweden	19	29	-10	100
20. Germany	18	13=	-4.5	20.25
21. New Zealand	17	24	-7	49
22. England	16	19=	- 2.5	6.25
23. Norway	15	5=	10	100
24. Denmark	14	18	- 4	16
25. United States	13	11	-2	4
26. Scotland	12	8	4	16
27. Latvia	11	36	-25	625
28. Spain	10	19=	-8.5	7725
29. Iceland	9	35	-24	576
30. Greece	8	19=	- 11	121
31. Lithuania	7	24	- 17	289
32. Romania	6	34	-28	784
33. Cyprus	5	19=	- 14.5	210.
34. Portugal	4	7	- 3	9
35. Iran	3	3	0	0

36. Colombia	2	2	0	0
37. South Africa	1	1	0	0

Σ = 6 625.5

$$\rho = 1 - \frac{6\,\Sigma D^2}{N(N^2 - 1)}$$

$$= 1 - \frac{6 \times 6\,625.5}{37(37^2 - 1)}$$

$$1 - \frac{39\,753}{50\,616}$$

$$= 1 - 0.785 = 0.215$$

Perhaps contrary to expectations and earlier findings, there appears to be only a moderate to low correlation between high national achievement and the number of books in students' homes. In the same way there is a similar low level of correlation between a limited number of books in a students' homes and low achievement. In reality these correlations may well be only a 'virtual' effect (especially in the latter case) since in the high population density countries such as Japan, Hong Kong and Singapore, apartments are very small, and large book holdings take up valuable space. Other factors that may influence book holdings by households are lack of available finance and cultural pressures that may discourage book ownership; while low publication rates in small language groups (for example, Iceland) and the climate, particularly in those countries which experience long winter nights or exceptionally mild conditions, may influence book ownership positively or negatively on a whole population basis. The availability, quality and accessibility of public and school libraries may also influence the purchase of books. On consideration of these factors and the calculated correlation coefficients, it would appear that book owning does influence achievement positively but only marginally.

From a more theoretical point of view (Gronlund and Linn, 1990: 63) there are of course a number of intrinsic factors that influence the magnitude of all correlation coefficients. Some of the basic factors are, for example, that larger correlation coefficients are obtained

- when the characteristics being measured are relatively similar;
- when the spread of scores is large;
- when the stability of scores is high; and
- when the time span between measures is short.

Figure 6.2 Basic factors influencing the size of correlation coefficients

Larger coefficients		Smaller coefficients
ALIKE	← Characteristics measured →	UNLIKE
LARGE	← Spread of scores →	SMALL
HIGH	← Stability of scores →	LOW
SHORT	← Time span between measures →	LONG

6.6 OTHER RESOURCES IN THE HOME

The questions for which data is provided in Table 6.25 were intended to examine the 'standard of living' and other home factors that may influence achievement either positively or negatively.

6.6.1 Commentary on facilities

Superficially, these frequency counts of home facilities reveal characteristics of developing countries such as only moderate availability of domestic utilities such as electricity and running water. The data appears to be self-validating in that the differences between the Upper Grade scores and the Lower Grade scores are for the most part slight.

Table 6.25 Facilities in the students' homes - South African data for Lower Grade and Upper Grade

FACILITY	Household facility	Percentage having the particular item	
Domestic facilities		UG	LG
	Electricity	60.4	61.4
	Running water	45.4	49.3
	Warm water	53.4	53.2
	Flush toilet	44.6	50.2
Personal Facilities			
	Desk or table	57.6	59.2
	Own room	59.1	56.3
	Dictionary	73.2	69.6
	Calculator	79.5	80.6
	Computer	12.3	12.4
Audio-visual facilities			
	Radio	89.3	90.6
	Television	74.0	75.5
	Video-player	34.6	36.1
	Tape recorder	62.2	59.5
	CD player	31.0	30.8
Access to transport		UG	LG
	Own bicycle	36.6	37.1
	Car available to family	41.8	44.6

Furthermore, the number of households with electricity shown in this sample (60.8 per cent) corresponds very closely with the ESKOM figure of 60 per cent (ESKOM, 1997). If 60 per cent of students at this level of education claim to have their own room and access to a study desk or table, learning conditions may not be nearly as disadvantageous as some opinions suggest.

Discussions with researchers who work in the field of housing in disadvantaged areas have suggested that this question may have been misinterpreted in that a student may well have responded 'yes' to the own room question in cases where the children in a family had a separate room from that used by their parents. In other words, an 'own' room may have been interpreted as a 'children's' room. Equally it has been pointed out that in the rural districts where building is carried out with few material costs, 'own' rooms may be fairly common. The question regarding access to a desk or table may have been treated as 'is there a table in your home?' This latter, whilst possibly true, was not the intention of the TIMSS questionnaire panel and thus this data may not be a reflection of learning conditions. Corroborative external evidence such as that obtained from ESKOM and a confirmation from Philips South Africa (Philips SA Ltd., 1997) concerning the fact that they sell a large number of battery powered television sets, as well as internal congruence between the two grades appear to confirm that the data to hand is essentially a description of reality.

With the sole exceptions of South Africa and Iran, over 90 per cent of students in all the participating countries claim to have calculators. In Austria, Iceland, the Netherlands and Singapore the level of access to calculators is 99 per cent or more.

Computers in the students' homes reveal a variable distribution. Table 6.25 above shows that 12.3 per cent of South African students have a computer in the home, while in England this figure is 90 per cent. This high level of access to computers contrasts with Iran (6.5 per cent), Bulgaria (2.3 per cent) and Thailand (4.7 per cent). Superficially there appears to be no relationship between the numbers of students having access to a computer at home and achievement.

6.7 EXTRAMURAL ACTIVITIES

It is of considerable interest to examine what junior secondary level students do in their time out of school.

6.7.1. EXTRAMURAL SCHOLASTIC ACTIVITIES

The findings of the questions in the TIMSS questionnaires addressed to students confirm substantially that, among teenagers, extra lessons are a major South African 'secondary industry'. Quite apart from Saturday morning schools and NGO programmes the larger township areas such as Soweto also display the phenomenon of 'Street Academies' which are largely 'fly by night' operations but fall within the range of the question. While the proportion of students who are paying for these extra lessons cannot be established, the following Tables 6.26 and 6.27 are instructive.

In the case of the Lower Grade respondents the picture of out of school scholastic activities is not dramatically different from Upper Grade as can be seen in the tables which follow (6.26 to 6.28). It should be remembered that the average age for both the South African groups is rather higher than the norm and therefore the proportion that appears to hold down some type of part-time employment may not be as indicative of exploitative 'child labour' practices as it may at first appear.

Table 6.26 Time spent on extra lessons - Lower Grade - South African data

LOWER GRADE	No Time per week	Less than 1 hour	1-2 hours	3 - 5 hours	More than 5 hours	Dnr
Extra Maths lessons	26.0%	36.7%	19.8%	5.3%	5.4%	6.8%
Extra Science lessons	26.1%	30.8%	21.2%	7.7%	3.8%	10.5%
Science Club	48.7%	14.8%	11.7%	7.5%	5.6%	11.8%
Paid job	54.3%	10.0%	8.1%	6.8%	8.3%	12.4%

Table 6.27 Time spent on homework per day - Lower Grade - South African data

Homework	None	Less than 1 hour	1-2 hours	3-5 hours	More than 5 hours	Dnr
Mathematics	7.9%	39.1%	28.5%	11.3%	7.7%	10.5%
Science	11.5%	35.4%	24.6%	10.5%	6.8%	11.2%
Other subjects	12.5%	27.0%	25.0%	14.2%	11.2%	10.1%

Table 6.28 International comparisons of time spent on homework - Lower Grade - South African data

	Country	None	< 2 hours/week	> 2 hours/week
MATHEMATICS	**South Africa**	7.98	67.6	19.0%
	Colombia	5.8	83.9	10.5
	Iran	1.4	73.0	26.7
	Thailand	4.0	91.2	4.8
SCIENCE	**South Africa**	11.5	60.0	17.3
	Colombia	5.3	83.6	11.2
	Iran	2.1	76.6	21.3
	Thailand	7.7	89.0	3.3

At the Lower Grade, in cases where students declare that they receive no homework, the South African students' data is somewhat higher than that of the other developing countries that participated in TIMSS. At the level where less than two hours per week are claimed, South Africa is substantially below the percentages of students from the other developing countries. In general it therefore appears that South African students spend less time on homework than students in other developing countries.

The impressions carried over from the homework data of the Upper Grade are supported by the data from the Lower Grade.

International comparisons with time spent on extra lessons and homework are particularly interesting in view of the 'time on task' comments and the relationship to achievement made in Chapter 2. These comparisons can be seen in Tables 6.29 and 6.30.

Table 6.29 International comparisons of time spent in extra lessons and paid jobs - Lower Grade

LOWER GRADE	No Time per week	<1 hour/ week	1-2 hours/ week	3-5 hours/ week	>5 hours/ week	Dnr
Extra Maths lessons: **South Africa**	**26.0%**	**36.7%**	**19.8%**	**5.3%**	**5.4%**	**6.8%**
Colombia	14.3	45.6	32.0	5.0	3.1	9.5
Iran	57.4	13.2	22.9	4.2	2.3	20.6
Thailand	74.5	8.9	14.3	2.0	0.3	6.5
Czech Rep.	45.2	36.2	15.1	2.5	1.0	2.4
Korea	49.8	10.9	25.1	8.3	5.9	1.3
Extra Science lessons: **South Africa**	**26.1%**	**30.8%**	**21.2%**	**7.7%**	**3.8%**	**10.5%**
Colombia	14.2	43.9	32.4	7.1	2.4	15.1
Iran	68.7	13.1	13.9	2.6	1.7	28.5
Thailand	79.8	7.7	11.1	1.2	0.1	7.3
Czech Rep.	40.4	32.3	21.3	4.7	1.3	2.9
Korea	74.6	8.3	12.7	2.7	1.6	2.2

	No time per week	<1 hour per week	1-2 hours per week	3-5 hours per week	> 5 hours per week	Dnr
Paid Job **South Africa**	**54.3**	**10.0**	**8.1**	**6.8**	**8.3**	**12.4**
Colombia	69.9	6.9	4.7	4.4	14.1	24.9
Iran	74.3	5.2	6.1	7.5	6.9	29.6
Thailand	65.7	11.7	10.8	4.5	7.4	6.7
Czech Rep.	80.4	6.3	6.3	2.8	4.2	4.0
Korea	94.9	2.6	1.6	0.5	0.3	2.9

It appears that the students of most nations spend considerable time on extra lessons. South African students on the whole appear to spend as much time as, if not more than many countries on extra lessons. Although it is sometimes assumed that many South African teachers are underqualified and under-skilled in classroom practices, TIMSS gathered no statistical data to demonstrate these assumptions.

Table 6.30 Time spent on extra lessons - Upper Grade - South African data

UPPER GRADE	No Time per week	Less than 1 hour	1-2 hours	3 - 5 hours	More than 5 hours	Dnr
Extra Maths lessons	21.6%	36.6%	20.2%	5.6%	5.5%	10.5%
Extra Science lessons	21.9%	28.4%	21.7%	7.1%	4.7%	16.2%
Science Club	37.6%	12.7%	14.7%	9.8%	7.0%	18.2%
Paid Job	42.0%	10.5%	8.8%	8.7%	12.2%	17.9%

Table 6.31 Time spent on homework per day - Upper Grade - South African data

Homework	None	Less than 1 hour	1-2 hours	3-5 hours	More than 5 hours	Dnr
Mathematics	9.0%	30.6%	24.1%	12.6%	8.7%	14.9%
Science	10.9%	30.1%	24.7%	12.0%	6.1%	16.1%
Other subjects	12.7%	22.7%	22.7%	15.3%	11.9%	14.6%

Table 6.32 International comparisons of time spent on homework - Upper Grade - South African data

	Country	None	Less than 2 hours per week	More than 2 hours per week
MATHEMATICS	South Africa	9.0	54.7	21.3
	Colombia	5.1	83.0	11.9
	Iran	1.3	73.3	25.4
	Thailand	4.5	90.2	5.3
SCIENCE				
	South Africa	10.9	54.8	18.1
	Colombia	6.1	85.3	8.6
	Iran	1.4	77.0	21.6
	Thailand	6.8	89.7	3.4

Table 6.33 International comparisons of time spent on extra lessons and paid jobs - Upper Grade

UPPER GRADE	No Time per week	Less than 1 hour	1-2 hours	3 - 5 hours	More than 5 hours	Dnr
Extra Maths lessons: **South Africa**	**21.6%**	**36.6%**	**20.2%**	**5.6%**	**5.5%**	**10.5%**
Colombia	16.2	39.9	32.7	7.4	3.7	
Iran	51.7	12.5	28.8	5.2	1.8	
Thailand	74.0	9.3	13.7	2.4	0.7	
Czech Rep.	47.9	32.0	16.7	2.8	0.6	
Korea	53.2	9.1	23.5	8.2	6.0	
Extra Science lessons: **South Africa**	**21.9%**	**28.4%**	**21.7%**	**7.1%**	**4.7%**	**16.2%**
Colombia	17.1	44.8	29.6	6.9	1.6	
Iran	64.6	13.9	16.8	3.6	1.1	
Thailand	78.4	8.3	11.1	1.8	0.4	
Czech Rep.	46.6	30.0	18.3	4.3	0.8	
Korea	78.9	5.7	11.3	3.0	1.1	
Paid Job **South Africa**	**42.2%**	**10.6%**	**8.9%**	**8.8%**	**12.4%**	**16.9%**
Colombia	67.6	4.8	5.2	6.2	16.2	
Iran	72.3	5.8	6.0	6.8	9.1	
Thailand	64.0	10.9	11.1	4.9	9.0	
Czech Rep.	76.0	7.9	6.9	3.6	5.6	
Korea	96.4	1.8	1.1	0.3	0.4	

Experience gained from association with EXPO for Young Scientists suggests that far fewer schools have Science Clubs than these returns reveal. There are similar reservations about other student responses to the questionnaire that recur throughout this analysis. However, whilst some evaluative comments are made where serious doubts are raised, the data has generally been interpreted in good faith.

6.7.2 EXTRAMURAL NON-SCHOLASTIC ACTIVITIES

The returns shown below (Tables 6.34 and 6.35) suggest that there has perhaps been a common misreading of these questions. The time spent on scholastic activities, enquired into in the previous question and discussed above, requires a 'per week' response, whereas the question dealing with recreational activities requires a per day response. This series of questions on activities may, however, have been misinterpreted by the students as also requiring a per week response. If this is not the case, the responses to these questions may serve to provide some view of the degree of misconcept held by junior secondary/middle school students with regard to the passage/value of time. On the other hand, the variations between the percentage responses for each grade are so small as to suggest that the data collected is, in fact, valid. If the validity of these returns is accepted, this raises an interesting question in terms of reading habits. Research such as Sander's (1993) into the matter of 'Do students read?' found that the majority of 'students do not read [or read very little]'; and yet in the TIMSS study only just over 12 per cent in at each grade claim not to read at all.

What is particularly disappointing about these questions dealing with extra mural activities and other questions later in the questionnaire is the consistent level of 'no response' at a 10 - 15% level. It can be assumed that for students with a poor mastery of the language, this was a fairly difficult and even fatiguing questionnaire in terms of complexity and length. This may have been a contributory factor to the lack of response.

Table 6.34 Extramural activities per day - Lower Grade - South African data

	No time	less than 1 hour	1-2 hours	3-5 hours	More than 5 hours	Dnr
TV and Videos	21.5	27.1	19.9	11.2	12.3	8.2
Computer games	49.5	18.5	11.4	5.2	4.1	11.3
Playing with friends	19.3	35.8	17.5	8.7	8.0	10.8
Sport	17.9	22.3	23.2	14.2	9.8	12.5
Jobs at home	12.0	26.4	24.6	14.9	10.8	11.3
Reading	13.4	32.2	22.3	11.2	8.7	12.2

Table 6.35 Extramural activities per day - Upper Grade - South African data

	No time	less than 1 hour	1-2 hours	3-5 hours	More than 5 hours	Dnr
TV and Videos	20.2	24.4	20.1	11.0	10.7	13.5
Computer games	41.4	19.4	12.4	5.2	4.5	17.1
Playing with friends	17.1	33.4	17.0	8.8	8.1	15.6
Sport	14.4	18.4	24.7	14.8	11.1	16.7
Jobs at home	10.6	21.9	25.0	15.5	11.7	15.4
Reading	12.2	26.1	22.1	12.6	10.1	16.9

The concerns raised by the *Pretoria News* (19 December 1996: 4) about the time spent by urban and periurban school children playing video games is reflected in these returns where over 40 per cent of students admit to spending time playing these games. Over 20 per cent admit to spending an hour or more per day using money they and, according to the *Pretoria News*, (see earlier in this paragraph) their parents cannot afford on this form of entertainment.

6.8 THE STUDENTS' OWN AND IMPUTED ATTITUDES TO MATHEMATICS AND SCIENCE

6.8.1 STUDENTS' PERCEPTION OF MOTHERS' ATTITUDES TO THE IMPORTANCE OF MATHEMATICS AND SCIENCE

In view of the fact that nearly half the students claim not to have domiciled fathers, it is pertinent to enquire into the values held by the mother of the family concerning education in terms of the influence that mothers can therefore exert on their children.

Table 6.36 Mothers' attitudes towards aspects of their children's education - Lower Grade - South African data

	Strongly Agree	Agree	Disagree	Strongly disagree	Dnr
I should do well in Natural Sciences	56.5	27.4	5.8	3.5	6.8
I should do well in Mathematics	59.3	22.8	6.4	4.3	7.1
I should do well in the language in which I am taught at school	63.2	19.1	5.2	4.5	7.9
I should be good at sports	38.2	31.8	12.9	7.7	9.4
I should have time to have fun	27.4	24.5	16.8	11.0	10.3
I should be in a class with high achieving students	38.3	29.6	13.6	9.8	8.8

Table 6.37 Mothers' attitudes towards aspects of their children's education - Upper Grade - South African data

	Strongly Agree	Agree	Disagree	Strongly disagree	Dnr
I should do well in Natural Sciences	49.5	28.0	7.8	4.7	4.7
I should do well in Mathematics	51.4	24.8	8.0	5.1	10.7
I should do well in the language in which I am taught at school	56.6	22.1	6.5	4.5	10.3
I should be good at sports	22.0	31.9	14.7	8.6	12.8
I should have time to have fun	21.2	31.3	20.7	12.5	14.3
I should be in a class with high achieving students	33.0	28.3	16.3	10.3	12.1

There is a marked consistency between the two grades. There is a detectable trend though, from Standard 5 to Standard 6, that doing well in Mathematics, Science and language of instruction becomes more important. This may reflect the mothers' changed expectations from primary school to secondary school for their children.

6.8.2 STUDENTS' PERCEPTION OF FRIENDS' ATTITUDES TO THE IMPORTANCE OF MATHEMATICS AND SCIENCE

Since peer group values are known to wield considerable influence on young people, it is of interest to investigate the values attributed to the respondents' friends concerning Mathematics and Science as well as other social issues.

Table 6.38 Aspects of friends' attitudes towards their education - Lower Grade - South African data

	Strongly Agree	Agree	Disagree	Strongly disagree	Strongly disagree
They should do well in Science	52.0	30.0	8.2	4.5	5.3
They should do well in Mathematics	54.5	27.5	7.1	4.6	6.3
They should do well in the language of instruction at school	58.4	24.0	6.6	4.3	6.7
They should have time for fun	31.7	34.4	14.9	10.3	8.7
They should be good at sports	40.3	33.3	12.0	6.9	7.5
They should be placed with high achieving class mates	35.7	30.4	17.1	9.2	7.5

Table 6.39 Aspects of friends' attitudes towards their education - Upper Grade - South African data

	Strongly Agree	Agree	Disagree	Strongly disagree	Dnr
They should do well in Science	44.0	31.0	10.5	5.5	9.0
They should do well in Mathematics	46.3	29.6	9.8	4.8	9.4
They should do well in the language of instruction at school	51.7	25.9	8.1	4.2	10.1
They should have time for fun	26.3	30.0	19.3	11.1	13.3
They should be good at sports	36.7	30.9	13.3	7.9	10.2
They should be placed with high achieving class mates	31.2	28.3	17.8	10.4	12.3

As with the mothers' attitudes, supposed peer attitudes are expressed in a similar range of percentages. In terms of Mathematics, Science and Language of instruction as educational priorities, agreement as to the importance of these subject focuses ranges from 70 to 80 per cent. As might be expected, appreciably more of the peers to the respondents are thought to place a higher value on sporting prowess. Class placement with high achieving class-mates appears to receive a 60 - 65 per cent support level.

6.8.3 PERSONAL ATTITUDES TO THE IMPORTANCE OF MATHEMATICS AND SCIENCE EDUCATION, LANGUAGE OF INSTRUCTION AND LIFE STYLE

The questionnaire shows that individual attitudes correspond highly with those imputed both to friends and to mothers. It is noticeable that fewer respondents (by several percentage points) were willing to reveal their own opinions than they were to reveal those they thought to be other people's; and yet both Mathematics and Science are regarded as being far more important to the student him/herself than the values attributed to either friends or mothers.

Table 6.40 Personal attitudes towards aspects of their own education - Lower Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I should do well in Science	62.1	23.7	4.7	4.0	5.5
I should do well in Mathematics	62.6	21.4	5.6	4.1	6.3
I should do well in the language of instruction	65.0	18.3	5.3	3.9	7.5
I should have time for fun	31.2	36.0	36.8	9.7	9.2
I should be good at sports	42.2	31.4	11.1	6.9	8.3
I should be placed in classes with high achieving class mates	39.6	28.6	14.8	9.3	7.6

Table 6.41 Personal attitudes towards aspects of their own education - Upper Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I should do well in Science	52.9	26.1	6.3	4.8	9.9
I should do well in Mathematics	53.4	24.4	7.7	4.4	10.0
I should do well in the language of instruction	56.3	21.5	6.9	4.0	11.4
I should have time for fun	25.3	31.1	19.2	10.4	14.1
I should be good at sports	38.5	30.0	12.2	7.3	12.0
I should be placed in classes with high achieving class mates	33.8	28.0	15.3	10.2	12.7

More Lower Grade students were inclined to answer these personal attitude questions than were the Upper Grade students. For both grades, the need to do well in Mathematics and Science remains levels of above 80 per cent.

6.8.4 INDIVIDUAL VALUES PLACED ON MATHEMATICS AND SCIENCE

Table 6.42 Individual values placed on Mathematics - Lower Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I enjoy learning Mathematics	54.5	28.5	7.1	4.7	5.1
Mathematics is boring	18.1	19.8	25.6	28.8	7.7
Mathematics is an easy subject	33.9	27.5	20.1	11.0	7.4
Mathematics is important to everybody	58.3	21.8	7.2	7.1	5.6
I would like a job involving Mathematics	46.6	26.8	11.8	9.0	5.8

Table 6.43 Individual values placed on Mathematics - Upper Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I enjoy learning Mathematics	46.7	29.7	8.9	5.6	9.1
Mathematics is boring	15.2	20.3	27.8	24.4	12.1
Mathematics is an easy subject	29.9	25.8	21.3	11.1	11.9
Mathematics is important to everybody	51.2	23.6	8.2	7.1	9.9
I would like a job involving using Mathematics	42.2	27.0	11.7	8.8	10.3

It appears that attitudes concerning Mathematics harden somewhat during the transition from Primary School to Secondary school in that the percentage enjoying Mathematics decreases (8 per cent), while the percentage finding Mathematics boring increases (+2.8 per cent). The overall importance of Mathematics also diminishes in the students' estimation (7.1 per cent).

Table 6.44 Individual values placed on Science - Lower Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I enjoy learning Science	55.6	28.3	5.7	4.5	6.0
Science is boring	17.1	22.3	24.1	27.9	8.6
Science is an easy subject	38.4	30.7	15.1	7.2	8.6
Science is important to everybody	50.2	25.6	10.2	6.3	7.6
I would like a job involving Science	42.3	26.4	13.6	10.0	7.6

Table 6.45 Individual values placed on Science - Upper Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I enjoy learning Science	47.7	30.4	7.1	4.7	10.1
Science is boring	15.6	21.2	26.9	22.8	13.5
Science is an easy subject	32.3	31.0	16.2	7.2	13.4
Science is important to everybody	42.4	27.2	11.3	7.0	12.1
I would like a job involving science	38.5	27.2	12.7	9.4	12.1

Positive personal attitudes towards Science also show a fall off from the Lower Grade to the Upper Grade in a manner similar to that shown towards Mathematics. Science evidently becomes somewhat less enjoyable, more difficult and less appealing as a career prospect.

6.8.5 AWARENESS OF HOW THE NATURAL SCIENCES CAN HELP IN SOLVING THE WORLD'S ENVIRONMENTAL PROBLEMS

Overall, there does not appear to be much faith shown in the ability of Science to address the world's pollution and environmental problems. A little over one quarter of the students apparently believe that Science has some of the answers to world pollution problems.

Table 6.46 Attitudes towards Science and world problems - Lower Grade - South African data

To what extent do you think that Science could address these problems?	Not at all	Very little	Some-what	A great deal	Dnr
Air pollution	30.3	23.2	12.6	28.2	5.7
Water pollution	22.0	25.5	14.8	29.8	8.0
Destruction of forests	21.8	22.5	20.5	25.5	9.7
Destruction of endangered species	23.1	21.5	18.9	25.9	10.6
Damage to the ozone layer	26.2	21.4	18.0	24.2	10.0
Problems with nuclear power stations	27.7	21.1	17.1	26.2	7.8

Table 6.47 Attitudes towards Science and world problems - Upper Grade - South African data

To what extent do you think that Science could address these problems?	Not at all	Very little	Some-what	A great deal	Dnr
Air pollution	31.8	24.7	11.1	22.0	10.3
Water pollution	23.6	28.3	12.8	22.6	12.7
Destruction of forests	21.8	23.2	19.2	20.7	15.1
Destruction of endangered species	22.6	22.6	19.4	20.1	15.4
Damage to the ozone layer	24.0	22.1	18.0	20.6	15.2
Problems with nuclear power stations	26.1	23.7	16.5	21.7	11.9

Whilst there appears to be no large scale differences between the Upper and Lower Grade returns, in all cases 65 per cent or more of the students do not indicate that these problems identified will be adequately addressed by Science.

Table 6.48 Which problem concerns the student most- Lower Grade - South African data

	% Responses
Air pollution	16.2
Water pollution	12.6
Destruction of forests	4.7
Endangered species	5.4
Damage to the ozone layer	5.5
Problems with nuclear power stations	3.3
Dnr	52.2

At the Lower Grade, when requested to identify which of the world's environmental problems concerned them the most, between 50 and 60 per cent of the students failed to respond. This low response level could be interpreted as a lack of knowledge, an alarming level of apathy or that local students simply had no answer to offer. Alternatively, even in circumstances where students have more immediate worries, such as local violence or the matter of food for the next meal, this 'no response' level of the returns perhaps indicates a failure of several national awareness programmes. Internationally, however, there are only small variations between the Upper Grade responses and the Lower Grade responses.

Table 6.49 Which problem concerns the student most- Upper Grade - South African data

	% Responses
Air pollution	11.8
Water pollution	10.6
Destruction of forests	3.4
Endangered species	6.0
Damage to the ozone layer	4.5
Problems with nuclear power stations	2.6
Dnr	61.2

The high level of failure to answer this question may be an indication of apathy about the environmental damage that South Africa is suffering. Internationally, this awareness is at a much higher level. Students in the European countries perceive (at the 30 per cent level) damage to the ozone layer as the most worthy problem for their concern; and with few exceptions, the response rate in Europe to this question was over 80 per cent at the Upper Grade level (compared to South Africa's 39 per cent).

6.8.6 CAREER PREFERENCES IN THE SCIENCES

Table 6.50 Career preferences in the Sciences - Lower Grade - South African data

Biology	34.1
Chemistry	7.7
Geography	21.5
Physics	19.3
Dnr	17.5

Table 6.51 Career preferences in the Sciences- Upper Grade - South African data

Biology	32.3
Chemistry	7.5
Geography	16.7
Physics	23.6
Dnr	20.0

The two tables (6.50 and 6.51), above, suggest strongly that there are problems associated with the image of Chemistry as a career prospect. Internationally, more than half the participating countries have submitted no data for this question. However, for those countries that are recorded in the international results tables, Chemistry, on average, is equal top option with Biology as a career preference for the Lower Grade students. In the Upper Grade the situation changes in that, with the exception of Cyprus, Chemistry falls off as a preferred career choice. This indication of career preferences may be more significant than the more general attitudes towards Science that have been discussed earlier in this chapter. It is also notable that the Chemistry questions were the lowest scoring field of Science, as discussed in 5.5.4.

The only readily discernible trend in career options between the Upper and Lower Grades is an increase in the preference for a career in Physics and a corresponding decrease in an Earth Sciences based career as the students become older. The preference for a career in Life Sciences at these two grades may be seen as a precursor to the subject choices that are likely to be made in Grade 10 [Standard 8] in two years' time.

6.8.7 PERSONAL ASSESSMENT OF OWN ABILITY AND PERFORMANCE IN MATHEMATICS AND SCIENCE

Table 6.52 Perceptions of the students' own abilities in Mathematics and Science - Lower Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I usually do well in Mathematics	46.4	36.4	9.6	3.9	3.7
I usually do well in Science	41.3	38.2	10.5	5.1	4.9

Table 6.53 Perceptions of the students' own abilities in Mathematics and Science - Upper Grade - South African data

	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
I usually do well in Mathematics	41.9	33.6	11.8	5.6	7.1
I usually do well in Science	37.0	37.1	11.0	6.1	8.7

The findings that arise from this question appear to belie the openly acknowledged fact that Mathematics and Science are generally regarded as 'killer subjects' (SABC-TV News, 1997). Three quarters of the respondents feel that they do well in both Mathematics and Science which does not correspond with the TIMSS achievement findings for the South African sample population. The responses to these questions underline the need for qualitative research to support these quantitative findings. It has been suggested that these 'optimistic' returns may reflect a strong need to achieve highly in Mathematics and Science rather than an assessment of actual performance.

6.9 IN-CLASS ACTIVITIES AND PEDAGOGIC PROCESSES

6.9.1 TEACHING METHODS

The record of teaching methods and the frequency with which specific activities take place in the classroom are an important part of the information that has been gathered from the students' questionnaire. This data provides an insight into what actually happens in Grade 7 and 8 classes.

As with so many sections of this Population 2 enquiry there is a remarkable concordance between the reported classroom practices for the Upper and Lower Grades, with the exception of aspects, that might have been expected to change between Primary and Secondary schooling, such as a reduction in the number of students who report time spent working in pairs or small groups (from 52.3 per cent [LG] down to 39.9 per cent [UG]). Also, as might be expected, the frequency of homework being set (reported as nearly always and fairly often) increases from 70.8 per cent at the Lower Grade to 75.7 per cent at the Upper Grade. In both grades, over 65% of the sample group report that copying notes from the board is either the norm or an activity that takes place 'fairly often'. Predictably, both grades show that relatively few students have regular access to computers. The 'frequent' use of calculators in class reported as 35 per cent is substantially lower than the proportion of the sample claiming to possess calculators (approximately 80 per cent as reported in Table 6.25

earlier in this chapter). This low use of calculators represents a facility available to students which is not capitalized on by the teachers.

Table 6.54 In-class activities and pedagogic processes - Mathematics - Lower Grade - South African data

When we start a new topic in class:	Almost always	Fairly Often	Occasionally	Never	Dnr
The teacher shows us how to do Mathematics problems	62.2	16.0	8.1	9.8	3.9
We copy notes from the board	43.2	21.6	14.2	14.1	6.9
We have a quiz or test	42.2	26.3	16.0	7.8	7.6
We work from worksheets or text-books on our own	40.9	22.5	13.7	14.9	7.9
We work on Mathematics projects	38.1	20.9	13.9	18.4	8.7
We use calculators	35.9	18.3	13.1	25.2	7.5
We use computers	10.3	9.4	7.2	63.1	10.0

When we start a new topic in class:	Almost always	Fairly often	Occasionally	Never	Dnr
We work together in pairs or in small groups	32.9	19.4	17.2	22.4	8.1
We use things from everyday life in problem solving	42.4	22.5	14.1	13.3	7.7
The teacher gives us homework	52.2	18.6	9.1	3.4	7.7
The teacher checks our homework	37.3	18.7	12.8	22.8	8.2
We begin our homework in class	63.5	15.7	7.8	5.0	8.0
We check each others homework	43.0	20.1	12.9	16.4	7.6
We discuss our completed homework	48.9	21.0	12.1	11.7	6.3

Internationally the analysis of classroom practices shows a remarkably wide variety of approaches to teaching, but it can be stated with some degree of certainty that a range of pedagogic principles appears to be regularly applied in South African classrooms. This begs the question: Why do South African students lag behind the international achievement levels? (see 5.5.2)

Table 6.55 In-class activities and pedagogic processes - Mathematics Upper Grade - South African data

When we start a new topic in class:	Almost always	Fairly often	Occasionally	Never	Dnr
The teacher shows us how to do Mathematics problems	57.9	13.3	8.8	11.9	8.0
We copy notes form the board	44.1	19.1	13.2	11.9	11.7
We have a quiz or test	37.3	23.3	18.5	8.3	12.5
We work from worksheets or textbooks on our own	38.2	21.4	13.5	14.6	12.2
We work on Mathematics projects	32.8	18.5	15.1	20.5	13.2
We use calculators	34.9	15.5	11.4	26.3	11.9
We use computers	9.8	9.0	7.8	59.3	14.1
We work together in pairs or small groups	24.8	15.1	18.7	28.6	12.8
We use things from everyday life in problem solving	35.7	19.9	15.7	16.5	12.2
The teachers gives us homework	62.5	13.2	9.1	3.1	12.1
We begin our homework in class	37.9	17.6	11.9	19.9	12.7
The teacher checks our homework	61.0	13.5	8.1	5.2	12.1
We check each others homework	39.6	16.2	12.8	19.2	12.2
We discuss our completed home-work	47.3	17.1	12.0	13.1	10.5

One of the contentions of this thesis has been that the upper primary school system appears to operate more efficiently than the lower secondary school system. This is supported by the observation that support services and enrichment programmes are far stronger at the Primary School level than they are for the Grade 8 level. Equally, the new found freedoms of secondary school inhibit most aspects of students' progress. Unpublished research carried out by the Molteno project (1997) confirms the wider use of a variety of pedagogic techniques in primary schools than in secondary schools. However, the TIMSS findings show that primary school teachers appear to exercise less direct control over homework than do secondary school teachers. The TIMSS enquiry into the application of pedagogic principles in the introduction of new topics is discussed in the following paragraphs.

6.9.2 TECHNIQUES USED IN THE INTRODUCTION OF NEW TOPICS - MATHEMATICS

The techniques used to introduce a new topic to students may well be a critical factor in the eventual mastery of the topic under consideration. Examination of Tables 6.54 and 6.55, above, suggest that the Lower Grade (Standard 5) teachers use a far wider repertoire of techniques than is frequently made use of by Upper Grade teachers. Their enquiries into the prior knowledge that the students bring to class with them appear to be far more extensive and regularly practised than in the case of the Secondary school teachers (70.3 per cent LG and 62.6 per cent UG). The importance of prior knowledge to learning processes has been discussed earlier in 2.1.4.2. In a similar manner, the primary school teachers appear to be more adept in their ability to relate school topics to the everyday experience of their students (64.5 per cent LG and 55.2 per cent UG). This is one indication of why the overall Lower Grade achievement levels are so close to the Upper Grade achievement levels (see comment on this aspect of the TIMSS findings in 5.4.1). Tables 6.56, 6.57 and 6.58, below, investigate the methods teachers use when introducing new topics to their classes. The South African range of percentages is well in accordance with the international data.

Table 6.56 New topics in Mathematics - Lower Grade - South African data - South African data

When we begin a new topic in class the teacher:	Almost always	Fairly often	Occasionally	Never	Dnr
Explains the rules and definitions	61.6	19.4	6.1	8.2	4.8
Discusses a story or problem related to everyday life	36.1	28.4	15.0	13.9	6.5
Allows us to work together in pairs or small groups	38.3	21.7	15.8	17.5	6.7
Asks us what we know related to the new topic	45.9	24.4	11.9	10.5	7.3
Talks while we look at the textbook	44.6	19.9	11.6	16.9	6.9
Asks us to solve an example related to the new topic	49.8	22.9	12.0	8.7	6.6

Table 6.57 New topics in Mathematics - Upper Grade - South African data - South African data

When we begin a new topic in class the teacher:	Almost always	Fairly often	Occasionally	Never	Dnr
Explains the rules and definitions	59.0	15.7	7.0	9.4	8.9
Discusses a story or problem related to everyday life	32.3	22.9	15.4	18.3	11.1
Allows us to work together in pairs or small groups	30.4	18.8	16.9	22.7	11.2
Asks us what we know related to the new topic	41.3	21.3	14.7	10.9	11.8
Talks while we look at the textbook	44.4	18.7	12.8	13.1	11.1
Asks us to so solve an example related to the new topic	48.3	19.7	12.7	10.0	10.3

Table 6.58 International comparative data - the introduction of new topics in Mathematics - Upper Grade

When we begin a new topic in class the teacher:	Almost always	Fairly often	Occasionally	Never	Dnr
Explains the rules and definitions. (South Africa)	59.0	15.7	7.0	9.4	8.9
Colombia	61.9	33.7	3.7	0.7	5.0
Iran	61.4	30.3	6.1	2.3	5.3
Thailand	70.1	23.8	5.0	1.1	0.9
Discusses a story or problem related to everyday life. (SA)	32.3	22.9	15.4	18.3	11.1
Colombia	24.4	25.1	32.0	18.5	8.6
Iran	17.7	18.9	37.0	26.5	7.9
Thailand	30.0	40.4	25.0	4.7	1.1

	Almost always	Fairly Often	Occasionally	Never	Dnr
Allows us to work together in pairs or small groups. (SA)	30.4	18.8	16.9	22.7	11.2
Colombia	34.9	30.7	26.9	7.5	8.1
Iran	24.7	19.1	24.8	31.3	9.8
Thailand	18.1	31.2	38.9	7.9	1.3
Asks us what we know related to the new topic. (SA)	41.3	21.3	14.7	10.9	11.8
Colombia	42.2	35.8	17.0	5.0	8.3
Iran	28.4	36.5	24.9	10.2	8.4
Thailand	40.2	44.9	13.3	1.6	2.0

	Almost always	Fairly often	Occasionally	Never	Dnr
Talks while we look at the textbook. South Africa	44.4	18.7	12.8	13.1	11.1
Colombia	27.3	23.6	28.2	21.0	8.5
Iran	16.4	18.3	17.5	47.8	8.4
Thailand	59.0	31.8	7.6	1.7	1.0
Asks us to so solve an example related to the new topic. (SA)	48.3	19.7	12.7	10.0	10.3
Colombia	50.9	36.3	11.1	1.7	7.3
Iran	53.2	31.7	11.9	3.2	7.5
Thailand	38.0	47.3	13.2	1.6	0.9

It is notable that Japanese teachers are recorded as referring to prior knowledge when introducing a new topic to their students 'only occasionally' or 'never' (70 per cent or higher for both grades).

6.9.3 THE INTRODUCTION OF NEW TOPICS IN SCIENCE CLASSES

In the case of the introduction of new topics into Science classes, the differences between Lower Grade teachers and Upper Grade teachers are less marked but nevertheless are still apparent.

Table 6.59 New topics in Science - Lower Grade - South African data

When we begin a new topic in class the teacher:	Almost always	Fairly often	Occasion-ally	Never	Dnr
explains rules and definitions	56.6	20.6	6.8	8.7	7.2
discusses a practical problem related to everyday life	39.2	30.6	12.4	9.5	8.3
allows us to work together on a problem or project	35.0	23.3	17.0	15.2	9.4
asks us what we know that is related to the new topic	43.5	25.7	12.5	8.9	9.4
talks while we look at the textbook	40.3	19.9	14.0	16.7	9.1
makes us try to solve a problem related to the new topic	45.0	23.4	13.2	9.7	8.7

The percentage of students reporting that the new topic is related, by the teacher, to everyday life is (always or often) 69.8 per cent Lower Grade compared to 59.4 per cent at the Upper Grade. Reference to prior knowledge shows similar discrepancies (69.2 per cent LG compared to 61.1 per cent at UG).

Table 6.60 New topics in Science - Upper Grade - South African data

When we begin a new topic in class the teacher:	Almost always	Fairly often	Occasion-ally	Never	Dnr
explains rules and definitions	54.8	17.0	7.6	9.4	11.2
discusses a practical problem related to everyday life	33.5	25.9	14.8	12.8	13.0
allows us to work together on a problem or project	32.0	19.9	15.8	18.5	13.9
asks us what we know that is related to the new topic	39.7	21.4	14.1	10.9	14.0
talks while we look at the textbook	43.0	19.2	13.6	11.0	13.2
makes us try to solve a problem related to the new topic	43.0	21.1	12.3	10.8	12.8

In the cases of both Mathematics and Science Teachers rely very strongly on presentation of rules and definitions to introduce new topics. This is reported as an average of 75 per cent of each grade of students.

6.9.4 REPORTED REQUIREMENTS TO DO WELL IN MATHEMATICS

Over 45 per cent of the Lower Grade respondents regard natural ability and talent as essential for success in Mathematics. At the Upper Grade this proportion is substantially reduced to 38 per cent. A similar trend is shown by the Lower Grade students who perceive that hard work out of school time is another essential requirement. For the Upper Grade the perspective of hard work being essential to success is reduced to just over 50 per cent of the respondents. Just over 40 per cent of respondents in both grades regard rote learning as an essential requirement for success in Mathematics. This perception of Mathematics as a memory exercise falls within the parameters of the school of thought discussed in 2.1.1.

6.61 Requirements to do well in Mathematics - Lower Grade - South African data

To do well in Mathematics you need	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
Lots of natural talent and ability	45.8	30.1	11.8	5.7	6.6
Good luck	42.2	26.8	15.1	9.4	6.5
to do a lot of hard work and studying at home	56.5	23.5	8.5	5.6	5.9
to memorize the textbook or notes	41.7	26.0	12.7	13.4	6.2

Table 6.62 Requirements to do well in Mathematics - Upper Grade - South African data

To do well in Mathematics you need	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
Lots of natural talent and ability	38.4	31.1	14.0	6.4	10.1
Good luck	41.3	27.4	13.8	8.0	9.5
to do a lot of hard work and studying at home	50.1	24.7	10.3	6.0	8.9
to memorize the textbook or notes	42.0	29.5	10.8	7.4	10.3

6.9.5 REPORTED REQUIREMENTS TO DO WELL IN SCIENCE

In the case of Science the supposed requirements for success are very closely aligned to the requirements for success in Mathematics. In both grades there is an over 70 per cent acknowledgement of talent being an essential requirement. As in the case of Mathematics there is a reduction from the Lower Grade to the Upper Grade of those students who regard hard work as an essential component of success. Reliance on memorizing notes and textbooks is, as was the case for Mathematics, in the region of 70 per cent. It is of interest that understanding, the ability to conceptualize or to solve problems were evidently not perceived as important factors in mastering Mathematics and Science by the compilers of the TIMSS student questionnaire which aligns the questionnaire compilers, subconsciously at least, with the behavioural psychologists point of view (see 2.1.1). The high percentages in both the Upper and Lower Grades who regard luck as a an essential component of success in Mathematics and Science (over 70 per cent) is also worthy of note.

Table 6.63 Requirements to do well in Science - Lower Grade - South African data

To do well in Science you need	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
Lots of natural talent and ability	44.7	30.6	12.1	6.2	6.5
Good Luck	41.6	26.3	14.9	10.0	7.2
to do a lot of hard work and studying at home	53.7	24.7	9.3	5.6	6.7
to memorize the textbook or notes	42.1	26.8	11.4	12.7	7.0

Table 6.64 Requirements to do well in Science - Upper Grade - South African data

To do well in Science you need	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
Lots of natural talent and ability	40.1	30.1	12.6	6.7	10.5
Good Luck	39.0	28.9	14.5	7.2	10.4
to do a lot of hard work and studying at home	47.8	26.1	10.5	5.6	10.1
to memorize the textbook or notes	41.6	30.0	10.1	8.0	10.3

6.9.6 ACKNOWLEDGED INCENTIVES FOR STUDENTS TO DO WELL IN MATHEMATICS

Table 6.65 Need to do well in Mathematics - Lower Grade - South African data

I need to do well in Mathematics	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
to get the job I want	56.4	24.9	7.4	6.1	5.1
to get into the secondary school or university I prefer	57.4	22.4	8.1	6.2	5.9
to please my parents	43.0	28.2	14.0	8.3	6.5
to please myself	56.2	23.3	7.4	7.1	6.0

Table 6.66 Need to do well in Mathematics - Upper Grade - South African data

I need to do well in Mathematics	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
to get the job I want	51.5	26.2	8.3	5.9	8.1
to get into the secondary school or university I prefer	48.9	25.6	9.1	6.6	9.7
to please my parents	36.6	30.4	15.2	6.7	11.1
to please myself	48.5	25.7	8.3	7.5	9.9

In both grades the reasons for doing well in Mathematics, pleasing parents is given the lowest rating. Just under 75 per cent (Upper Grade) and slightly more of the Lower Grade students regard doing well as important to themselves.

6.9.7 ACKNOWLEDGED INCENTIVES FOR STUDENTS TO DO WELL IN SCIENCE

Table 6.67 Need to do well in Science - Lower Grade - South African data

I need to do well in Science	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
to get the job I want	52.8	25.8	8.7	6.2	6.4
to get into the secondary school or university I prefer	52.4	25.1	9.1	6.1	7.3
to please my parents	39.8	29.6	15.0	8.1	7.5
to please myself	53.6	23.7	7.3	8.2	7.2

Table 6.68 Need to do well in Science - Upper Grade - South African data

I need to do well in Science	Strongly agree	Agree	Disagree	Strongly disagree	Dnr
to get the job I want	47.6	26.9	9.1	6.1	10.3
to get into the secondary school or university I prefer	44.4	25.1	11.7	6.6	12.1
to please my parents	36.3	31.7	13.1	6.5	12.4
to please myself	45.0	26.7	8.2	8.2	11.9

In the case of Science, self-interest is at on a par with other reasons for doing well in Mathematics and Science. As with Mathematics, though, Science, pleasing parents by doing well comes last on the list but is still at quite a high level (36 per cent or greater).

6.10 NEGATIVE AND ANTI-SOCIAL BEHAVIOUR IN SCHOOL

6.10.1 NEGATIVE AND ANTI-SOCIAL BEHAVIOUR IN SOUTH AFRICAN SCHOOLS

Under the heading of negative and anti-social behaviour in school, virtually all the responses for various activities appear to be lower than common opinion tends to suggest, or as recorded in documents such as those written by Jansen, (1993: 83 - 115) and Maja (1997). Regular missing of classes (more than 3 times per month) is reported at a level of below 15 per cent of the respondents. Reports of friends skipping classes occur at a higher rate. Nearly half of the respondents in both grades report friends missing class once or more in the past month.

Indicative of the climate of unrest in the country, forty per cent or more of students report themselves or their friends being involved in school violence or threat of violence.

Frequent theft is a far more common event, reported by over 55 per cent of the students in both grades (happening to them one or more times in the previous month). Theft of personal property appears to be nearly twice as common among the Upper Grade students as among the Lower Grade students.

Table 6.69 Negative behaviour in school - Lower Grade - South African data

Responses - how often did these events occur in the past month	Never	Once or twice	3-4 times	5 times or more	Dnr
I skipped a class	69.3	15.6	5.7	4.6	4.8
Something of mine was stolen	37.7	34.3	10.9	10.7	6.4
I thought another student might hurt me	52.0	23.6	10.2	5.8	7.4
Some of my friends skipped classes	49.6	24.2	10.7	8.9	6.7
Some of my friends had things stolen	39.9	31.1	12.8	8,5	7.8
Some of my friends were hurt by other students	44.3	28.4	11.8	9.4	6.1

Table 6.70 Negative behaviour in school - Upper Grade - South African data

Responses - how often did these events occur in the past month	Never	Once or twice	3-4 times	5 times or more	Dnr
I skipped a class	63.0	17.9	6.2	4.8	8.2
Something of mine was stolen	41.9	30.9	20.8	6.3	10.0
I thought another student might hurt me	46.6	25.0	11.1	5.7	12.1
Some of my friends skipped classes	42.7	26.3	11.0	9.2	10.8
Some of my friends had things stolen	41.6	26.7	12.6	7.3	11.9
Some of my friends were hurt by other students	41.6	27.8	11.3	9.3	10.1

The picture of in-school negative behaviour, shown in Tables 6.69 and 6.70, above, is starkly different from the picture drawn by other South African researchers such as Jansen (1993) and Maja (1994). These two reports are discussed in the some detail in the concluding chapter of this thesis. Internationally, behaviour in the schools of selected countries is recorded as follows:

6.10.2 COMPARATIVE ASPECTS OF NEGATIVE AND ANTI-SOCIAL BEHAVIOUR IN SCHOOL - LOWER AND UPPER GRADES

Table 6.71 Comparative aspects of negative behaviour reported in schools in other countries - Upper and Lower Grades

NOTE: The question that was put to the students was 'How often did these events occur in the past month?'

Question: MISSING CLASSES	Country	Never		1-4 times		5 or more times	
How often did you skip a class?		UG	LG	UG	LG	UG	LG
	South Africa	63.0	69.3	24.1	21.3	4.8	4.6
	Colombia	70.1	79.2	27.9	19.9	2.0	0.9
	Iran	57.4	50.9	38.4	44.8	4.2	4.4
	Thailand	86.4	91.4	12.9	8.4	0.7	0.3
	Austria	76.5	82.3	19.2	14.7	4.3	3.1
	Czech Rep.	92.5	96.3	6.5	3.0	1.0	0.7
	United States	82.6	87.9	14.7	10.2	2.7	1.9

As the statistics in all cases of anti-social behaviour are higher and therefore of greater concern to society in the Upper Grade, these figures are presented first. Attendance in class appears to be a fairly variable problem. The South African students have one of the lowest figures for students claiming never to have missed a class but even this figure would appear to be high in terms of the reports of Jansen (1993) and Maja (1994). It has also been pointed out that there may be a clear distinction in the students minds between the 'conscious' deliberate missing of classes and the situation where classes are missed 'by chance' or for non-deliberate reasons (for example not going to a class when the teacher is not present in the classroom). The Czech figures are remarkably high for full attendance. Virtually all the former Eastern European countries, with the exception of what was Czechoslovakia, such as Latvia (55.5 per cent claim never to have skipped a class), Lithuania (59.0 per cent) and Romania (44.3 per cent) have poorer admitted attendance rates than the South African figure. With surprisingly few exceptions, there seems to be poorer attendance in classes for the Upper Grade than for the Lower Grade.

Table 6.72 Comparative data describing the frequency with which students experience theft

The question that was put to the students was 'How often did these events occur in the past month?'

Question: THEFT	Country	Never		1-4 times		5 or more times	
How often have you had something stolen?		UG	LG	UG	LG	UG	LG
	South Africa	41.9	37.7	51.7	45.2	6.3	10.7
	Colombia	48.5	44.6	45.0	47.6	6.5	7.8
	Iran	73.4	64.9	24.5	30.4	2.0	4.8
	Thailand	43.0	41.1	52.5	54.6	4.5	4.3
	Austria	73.8	69.0	24.3	29.5	1.9	1.6
	Czech Rep.	68.1	66.1	30.5	32.5	1.5	1.4
	United States	53.2	48.2	43.4	47.2	4.5	4.6

Theft appears to be an international problem, which with notable exceptions such as Belgium (Fl.) (82.5 per cent), Bulgaria (92.8 per cent) and Sweden (90.5 per cent) - not shown on the tables. Most countries report experiences of theft in the past month at the 25 - 40 per cent level. Only Hungary (11.9 per cent of students have not experienced theft in the past month) reports frequent theft as occurring more often than in South Africa.

In-school violence, presumably predominantly bullying, is consistently more common in the Upper Grade reports than in the Lower Grade. This could perhaps be ascribed to older, more senior students, being in the same school. Those students who thought that they had never been in situations where they might have been hurt in South African schools are far fewer than almost all other reporting nations. Only Romania (32.8 per cent) reports a lower figure for this question of not having experienced violence in the past month.

Table 6.73 Comparative data describing the frequency with which students experience violent situations in school

The question that was put to the students was 'How often did these events occur in the past month?'

Question: VIOLENCE	Country	Never		1-4 times		5 or more times	
How often have you thought you might be hurt?		UG	LG	UG	LG	UG	LG
	South Africa	46.6	52.0	36.1	23.6	5.7	5.8
	Colombia	74.5	67.8	23.4	28.5	2.0	2.7
	Iran	83.4	76.0	15.5	20.3	1.1	3.8
	Thailand	77.7	77.4	21.6	23.3	3.0	3.4
	Austria	80.1	76.7	18.7	21.4	1.2	2.0
	Czech Rep.	71.1	69.6	26.3	27.4	2.7	3.0
	United States	75.5	73.2	21.6	23.3	3.0	3.4

Table 6.74 Comparative data describing the frequency with which students' friends miss classes

The question put to the students was 'How often did this event occur in the past month?'

Question: MISSING CLASSES	Country	Never		1-4 times		5 or more times	
How often did your friends skip a class?		UG	LG	UG	LG	UG	LG
	South Africa	42.7	49.6	37.3	34.9	9.2	8.9
	Colombia	20.6	25.3	63.5	60.4	15.9	14.4
	Iran	20.9	23.0	65.6	62.0	13.5	15.0
	Thailand	19.8	28.2	61.1	48.3	19.2	13.5
	Austria	37.5	48.9	45.8	39.5	16.7	12.5
	Czech Rep.	54.4	67.6	33.5	24.9	12.2	7.5
	United States	49.7	57.7	39.0	33.6	11.3	8.7

As already argued with reference to the South African data, it is a persistent phenomenon that the students answering this question of absence from class for their friends are less generous than they are in reporting their own behaviour. Friends are reported as missing classes far more frequently than themselves. From this set of data, it would appear that truancy from classes is both a fairly frequent event and even a majority of students miss more than one class to the extent of between 50 and 60 per cent or more in a month. The South African figure for the persistent missing of classes is lower than that of several other nations.

Table 6.75 Comparative data describing the frequency with which students' friends experience theft

The question put to the students was 'How often did this event occur in the past month?'

Question: THEFT	Country	Never		1-4 times		5 or more times	
How often did your friends have something stolen?		UG	LG	UG	LG	UG	LG
	South Africa	41.3	39.9	39.6	43.9	7.3	8.5
	Colombia	69.6	62.7	27.6	33.3	2.8	4.1
	Iran	54.2	49.7	42.1	43.6	3.7	6.8
	Thailand	22.3	21.8	69.9	71.1	7.8	7.2
	Austria	57.6	48.0	39.5	48.3	2.9	3.7
	Czech Rep.	49.4	52.1	47.7	45.5	2.8	2.4
	United States	42.5	38.9	51.9	55.0	5.6	6.2

Reports of friends losing possessions vary only a little from the reports of personal losses. The Colombian reports of no experience of theft in the past month are relatively low (69.6 per cent [UG] and 62.7 per cent [LG]).

International reports of friends being threatened with violence is widespread, with the South African figure for the respondent's friends never having experienced situations (in the past month) in which they might be hurt being one of the lowest recorded.

Table 6.76 Comparative data describing the frequency with which students' friends experience violent situations

The question that was put to the students was 'How often did these events occur in the past month?'

Question: VIOLENCE	Country	Never		1-4 times		5 or more times	
How often did your friends think they might be hurt?		UG	LG	UG	LG	UG	LG
	South Africa	41.6	44.3	39.1	40.2	9.3	9.4
	Colombia	56.8	50.2	40.6	44.7	2.6	5.1
	Iran	51.9	46.1	42.2	45.8	5.8	8.1
	Thailand	39.8	39.6	55.2	54.9	4.5	5.6
	Austria	57.2	55.5	39.9	40.7	3.0	3.9
	Czech Rep.	54.1	52.1	40.6	43.1	5.3	4.8
	United States	60.8	58.6	34.7	35.3	4.5	6.1

6.11 PERSONAL NON-SCHOLASTIC ACTIVITIES

6.11.1 CULTURAL ACTIVITIES

It is under the heading of non-scholastic activities that serious uncertainties begin to appear in the collected data. It is certainly doubtful if a sufficient number of the sample population live in areas where 30 per cent or more of them are able to visit a museum or go to the theatre on a weekly basis or more often. However, the responses to these questions may well lie in cultural differences as to what a theatre actually constitutes. It is these uncertainties, coupled with the heavy overburden of common misconcepts displayed in answers to the achievement tests described in Chapter 5, that suggest a serious short-coming of TIMSS in South Africa. What appears to be lacking is qualitative research/case studies accompanying the testing programme. It is only through qualitative/case study investigations that these types of apparently anomalous responses can be verified, disproved or clarified. This topic will be discussed further in Chapter 7.

Table 6.77 Personal activities - Lower Grade - South African data

	About every day	About once a week	About once a month	Rarely	Dnr
Read a book or magazine	43.1	30.7	7.7	10.4	8.0
Visit a museum or art exhibition	10.4	22.7	19.2	36.1	11.6
Attend a concert	15.5	20.6	23.0	28.8	12.0
Go to the theatre	13.3	17.0	16.8	40.1	12.7
Go to the 'movies'	21.1	23.0	20.2	25.5	10.3

Table 6.78 Personal activities - Upper Grade - South African data

	About every day	About once a week	About once a month	Rarely	Dnr
Read a book or magazine	44.1	29.8	6.9	8.3	10.8
Visit a museum or art exhibition	10.1	22.2	21.7	29.5	16.5
Attend a concert	15.7	21.4	22.2	24.1	16.5
Go to the theatre	12.5	18.9	19.3	31.8	17.5
Go to the 'movies'	19.3	21.9	20.5	21.5	14.7

Table 6.79 (a) International comparisons of the personal activities of students

	About every day		About once a week		About once a month		Rarely		Dnr	
Read a book or magazine	UG	LG	UG	LG	UG	LG	UG	LG	UG	LG
South Africa	44.1	43.1	29.8	30.7	6.9	7.7	8.3	10.4	10.8	8.0
Colombia	28.8	36.7	38.7	38.4	16.1	11.6	16.5	13.3	12.1	12.1
Iran	-		-		-		-		-	
Thailand	30.0	25.8	42.4	41.1	9.5	10.1	18.0	23.0	2.5	3.3
France	-		-		-		-		-	
Canada	41.4	44.0	32.2	28.5	10.1	9.1	16.4	18.4	4.9	5.6
Korea	25.9	25.4	42.3	40.7	19.1	16.1	12.7	17.8	2.3	3.7

Table 6.79 (b) International comparisons of the personal activities of students - continued

	About every day		About once a week		About once a month		Rarely		Dnr	
Visit museum or Art Expo	UG	LG	UG	LG	UG	LG	UG	LG	UG	LG
South Africa	10.1	10.4	22.2	22.7	21.7	19.2	29.5	36.1	16.5	11.6
Colombia	1.6	5.1	8.0	9.9	22.0	20.7	68.4	64.3	15.3	15.3
Iran	-		-		-		-		-	
Thailand	1.9	1.9	6.7	6.7	21.4	22.1	69.9	67.8	2.8	3.8
France	-		-		-		-		-	
Canada	0.6	1.1	2.0	2.1	12.2	16.2	85.2	80.6	5.6	6.2
Korea	0.7	0.8	2.3	3.9	19.2	24.7	77.8	70.6	2.4	3.8

Table 6.79 (c) International comparisons of the personal activities of students - continued

Attend a concert	About every day UG	LG	About once a week UG	LG	About once a month UG	LG	Rarely UG	LG	Dnr UG	LG
South Africa	15.7	15.5	21.4	21.7	22.2	23.0	24.1	28.8	16.5	12.0
Colombia	8.3	10.0	11.1	10.5	23.2	21.5	57.4	57.9	14.5	15.5
Iran	-		-		-		-		-	
Thailand	14.4	12.2	28.8	26.3	11.0	10.8	45.8	50.7	3.0	4.0
France	-		-		-		-		-	
Canada	1.4	1.8	2.4	3.3	19.2	16.8	77.0	78.1	6.5	7.1
Korea	0.6	0.8	1.7	2.9	10.9	12.0	86.7	84.3	2.4	3.8

Table 6.79 (d) International comparisons of the personal activities of students - continued

Go to theatre	About every day UG	LG	About once a week UG	LG	About once a month UG	LG	Rarely UG	LG	Dnr UG	LG
South Africa	12.5	13.3	18.9	17. 0	19.3	16.8	31.8	40.1	7.5	12 .7
Colombia	2.7	5.2	9.7	12.2	23.7	22.0	63.9	60.5	15.5	15.7
Iran	-		-		-		-		-	
Thailand	29.8	31.3	14.5	14.2	10.5	11.4	34.3	43.1	2.9	3.8
France	-		-		-		-		-	
Canada	1.3	1.9	5.0	7.2	18.3	20.5	75.3	70.5	7.6	7.7
Korea	0.9	0.9	1.4	1.9	8.4	11.9	89.3	85.3	2.5	3.8

Table 6.79 (e) International comparisons of the personal activities of students - continued

Go to movies	About every day UG	LG	About once a week UG	LG	About once a month UG	LG	Rarely UG	LG	Dnr UG	LG
South Africa	19.3	21.1	21.9	23.0	20.5	20.2	21.5	25.5	17.4	10.3
Colombia	6.5	9.4	22.0	19.2	33.6	29.9	37.8	41.4	14.0	14.1
Iran	-		-		-		-		-	
Thailand	35.9	37.6	21.2	18.8	25.6	24.6	17.3	18.9	2.4	3.3
France	-		-		-		-		-	
Canada	2.7	4.1	23.7	24.2	49.9	44.8	23.6	27.0	6.0	7.0
Korea	1.1	1.4	5.1	5.1	34.9	29.2	59.0	64.4	2.7	4.0

To a large extent participation in the types of activities listed in the TIMSS student questionnaire reflect cultural predilections and preferences. It is noticeable how few of the high achieving Korean students spend time on activities such as 'movies' and concerts and other activities away from home. South African students in the sample appear to spend well above the average amount of time in non-scholastic activities. Certainly it is apparent that the South African students participate in these activities to a greater extent than their counterparts in the other developing countries. The only observable exception to this is the Thai attendance at the cinema.

6.11.2 TELEVISION VIEWING PREFERENCES

Despite the fact that only just over one third of the students report having television at home (36.1 per cent for the Lower Grade and 34.6 per cent for the Upper Grade), reported viewing is substantially higher. Obviously, visiting the homes of friends or other places with television would elevate the viewer numbers.

Many of these returns - combined with the amount of time spent on homework and on extra lessons - suggest either that many students believe they are living a thirty hour day or this combined data reinforces the opinion expressed earlier that these students have little realistic value of time or a valid sense of time. Viewing preferences are News and Sports programmes, with popular music following close behind. Somewhat surprisingly, while the rate for watching cartoons is fairly high for the Lower Grade (over 50 per cent watching these programmes once a week or more), the proportion of Upper Grade students admitting to watching cartoons once a week or more is just under 19 per cent. The high level of non-responses (in all cases over 10 per cent and in some cases as high as 18 per cent) probably makes this data unreliable irrespective of the findings.

Table 6.80 Television viewing preferences - Lower Grade - South African data

	About every day	About once a week	About once a month	Rarely	Dnr
News or documentaries	46.9	20.2	7.1	15.1	10.8
Opera, ballet or classical music	23.9	26.0	12.5	24.5	13.2
Nature, wildlife or history	34.7	25.8	13.2	13.0	13.3
Popular music	38.6	24.9	10.9	12.5	13.1
Sports	38.6	28.3	9.6	10.7	12.8
Video games	26.3	21.1	12.4	26.6	13.6
Cartoons	29.2	18.7	12.2	25.7	14.2
Comedy, adventure or suspense	34.3	22.3	12.0	8.9	12.5

Table 6.81 Television viewing preferences - Upper Grade - South African data

	About every day	About once a week	About once a month	Rarely	Dnr
News or documentaries	40.2	21.0	7.7	16.3	14.7
Opera, ballet or classical music	22.2	25.4	14.1	20.7	17.6
Nature, wildlife or history	30.0	25.3	14.6	12.9	17.3
Popular music	36.0	23.8	11.4	11.4	17.3
Sports	39.5	25.5	9.7	9.6	15.8
Video games	23.3	22.9	14.1	22.4	17.2
Cartoons	19.9	17.9	14.3	29.2	18.7
Comedy, adventure or suspense	29.1	19.5	15.0	19.6	16.8

6.12 OVERVIEW AND SUMMARY

This chapter has examined the student profiles from an analysis of their responses to the TIMSS questionnaire which supplements the information obtained from the Mathematics and Science tests. The recognition of the importance of this additional data takes its impetus from the inherent difficulties of uncontextualized educational measurement where measurement (Bachman, 1990: 18) is:

> the process of quantifying the characteristics of persons according to explicit procedures and rules.

As Angoff (1971: 545) stresses:

> Today, educators are far less certain that there is a clear distinction between ability and achievement, just as they are less certain today of the distinction between nature and nurture, concepts that very likely led to the formulation of *ability* (or aptitude) and *achievement* as separate and separable entities. In any case, it has become clear that the conceptual distinction between measures of aptitude and measures of achievement is not always a sharp one, and so the distinction is often made operationally, for example, achievement tests consist of items that are closely dependent on the material explicit in the curriculum ... aptitude tests are not.

There appears to be a considerable hiatus between the questionnaire data and the test results. Internal evidence suggests that the range of didactic techniques, for example, is varied and compare to some extent with international returns. However, despite this variety of teaching skills in evidence, the attainment is very low. Homework appears to be issued at an adequate level and satisfactorily checked and controlled. Extra lessons are available and taken advantage of by over 60 per cent of the students in the sample at both grades. The causes of the anomaly that appears to exist between teaching and achievement is highlighted by the language problem discussed extensively (see 6.3.4 and 6.4 ff.) and is examined closely in the Conclusion to this thesis.

This investigation is entering in to very uncertain areas if the data analysed is either summarily refuted or devalued. In general terms, both internal validity (between the Lower and Upper Grades) and external attempts to validate the data testify to the overall acceptability of the data.

Reported attitudes, imputed mothers' and friends' attitudes, career choices, with the notable exception of Chemistry and self-esteem with regard to personal achievement in Mathematics and Science, all point to a functioning education system in South Africa that should therefore enable students to achieve at a satisfactory level.

In addition to the above observations, the significant findings that emerge from the students' questionnaire include:

- there is a teaching and learning problem associated with mastery of the language of instruction;
- the number of persons living in students' homes (commonly five or more) which may not be conducive to study;
- the high average age and age range of classes;
- the low level of enrichment of the learning environment that the students live in, in terms of the few books in the students' homes;
- the relatively high proportion of homes without electricity and other domestic services;
- the apparent failure of classroom tuition and the 'support industry' of extramural tuition and extra classes;
- the excessive reliance of South African teachers on textbooks for classroom teaching; and
- the large proportion of students who claim to use the language of instruction out of school (78 per cent) and the correspondingly low proportion (21 per cent) who claim never to use the language of instruction in their homes.

However, the underlying factor influencing South African achievement in Mathematics and Science is the matter of 'time on task' which is discussed more fully in the concluding chapter where qualitative investigations are referred to extensively.

CHAPTER 7

CONCLUSION

7.1 INTROIT

The purpose of this study was to examine, through the medium of TIMSS, the status of South African Mathematics and Science education as it was towards the end of 1995. The educational implications of this study focus on the need for a comprehensive national picture of the attainment levels in these important subject focuses with the primary intention of establishing bench-marks for the new political and educational dispensation.

In view of the large number and wide range of Aims, Objectives and Premises, set out in 1.1.2.2, 1.1.2.3 and 1.1.2.4 respectively, it appears logical to deal with these intentions individually so as to examine what the TIMSS programme can reveal about the aspects of South African Mathematics and Science education dealt with.

7.2 THE AIMS OF THIS STUDY AS SET OUT IN CHAPTER 1

The aims, as stated in Chapter 1, are mainly concerned with domestic South African issues rather than with the international panorama of Mathematics and Science education.

7.2.1 AN OVERVIEW OF SOUTH AFRICAN ACHIEVEMENT

AIM 1

To obtain a realistic view of South African Mathematics and Science achievement in an international context compared with developed and developing countries.

International studies of student achievement provide valuable comparative information about student performance and instructional practices. Inherent in the benefits of international studies, there are challenges and potential pitfalls associated with comparing achievement across countries, cultures and languages. As has been argued, in TIMSS, extensive efforts were made to attend to these issues through careful planning and documentation, co-operation among the participating countries, standardized procedures, and rigorous attention to quality control throughout.

This thesis has placed particular emphasis on South Africa's place among other developing countries. The four tables in Chapter 5 (Tables 5.5 to 5.8) show clearly the low ranking of South African performance in the TIMSS testing process. The overall South African performance is appreciably lower than even those of Colombia and Iran, in both Mathematics and Science.

7.2.2 THE SOUTH AFRICAN SAMPLE AND ITS ACHIEVEMENT

AIM 2

To select and interpret the profile of a large population of South African students and to examine how this profile relates to student achievement in a Mathematics and Science Study [TIMSS].

The focus of Chapter 6 lies in an analysis of the South African student questionnaires. It is apparent from these returns and other non-TIMSS related research (Maja, 1995: 33) that whilst general achievement is low, the primary schools appear to be functioning at a more efficient level than the secondary schools. The primary school teachers show a wider and more frequently used range of classroom techniques; they administer homework more regularly and they appear to have fewer disciplinary problems and negative behaviour to deal with (see 6.7.1). Maja (1995: 33) corroborates this impression:

> Most primary schools in Soweto operate normally with discipline enforced at all costs. When pupils come into the secondary schools and see teachers not attending their classes, they easily fall into the habit of coming to school to play.

The shortcomings of First World bias of the questionnaire instrument are numerous but these faults serve only to add some uncertainty to the findings, not to devalue them completely. For example, as already stated in the preceding chapter, there was no method to indicate that the respondents' parents had had no education at all. Furthermore, in a Third World context, several questions begged misinterpretation. For instance, the question enquiring into whether or not the student had 'his/her' own room (see 6. 6.1) has a particularly African connotation whereby this could have been interpreted to mean a 'children's room', in which no adult sleeps.

Another unforeseen problem area in South Africa was the age range of students in Grades 7 and 8 which was far beyond the data base permitted range (limited to sixteen years); as was class size (up to eighty where the limit was forty-five). Having twenty-three and twenty-four year old students in Grade 7, as in the South African case, caused some concern in the International Data Processing Centre.

7.2.3 THE ECONOMIC FUTURE

AIM 3

To derive a prognosis for South Africa's future economic development as it may be influenced by the outcomes of the current education system.

If Serageldin's (1995) revised criteria for the ranking of the wealth of nations and the linking of national prosperity to investment in Human Resource Development is valid, the much publicized intentions to restore a 'culture of teaching and learning' to South African schools must become a national priority in the immediate future. Maja (1997) makes the point that White Papers and Departmental Directives do not address this problem in the classroom. While legislation may have the effect of making political leaders appear to be active, the cascade effect down to the classroom is not as yet having noticeable effects. South Africa's economic future, in terms of its present educational standards and output, will not be a bright one unless urgent steps are taken to redress deficiencies in the management of education.

Loss of manpower is a growing problem for South Africa. Emigration, black and white, and adjustment of teacher/student ratios are draining South Africa of irreplaceable human resources. Immigration from other African countries (*The Citizen*, 6 January 1997) is straining the capacity of the education system and not apparently adding to the national skills pool. Such statements are being made despite the fact that the questionnaire returns do not show a more that 10 per cent immigrant component among the student respondents. However, these statistics may not have validity in that (as noted in Chapter 6) the reliability of the data may have been prejudiced by students concealing their expatriate status. Many countries have a larger immigrant component (see 6.3.1).

7.2.4 WEAKNESSES AND STRENGTHS IN SOUTH AFRICAN ACHIEVEMENTS

AIM 4

To identify, at a national level, the successes and weaknesses in teaching and learning Mathematics and Science.

As pointed out in 5.5.3 and 5.5.4, there are no high scoring fields in the South African achievement profile in the TIMSS test papers. Maja (1995: 23) makes the point that 'large scale qualitative studies tend to homogenize schools and to overlook the "within school dynamics" that influence the context of teaching and learning', and whilst this may be entirely correct from a qualitative view point, an infinite or even a large number of case studies is neither feasible nor likely to provide a clearer national picture of achievement or of many other educational factors than this study of TIMSS has done. TIMSS is intended to give a picture of the state of the nation, with subdivision into aspects that provide national pictures likely to be of value. However, one of the serious shortcomings of TIMSS is its lack of detail in terms of qualitative information. There is no disputing the fact that top South African students are able to hold their own with their equals from anywhere else in the world. The finding that only two per cent of South African students are in the fiftieth percentile (internationally) is a disappointing picture of South African education. The national picture does, however, give a prognosis of the quality of the young worker who will enter the work-force in four or five years' time and what the 'average' capacity is likely to be.

7.2.5 OPPORTUNITIES FOR IMPROVEMENT

> AIM 5
>
> To explore a variety of opportunities that exist to up-grade attainment levels in Mathematics and Science by examining where learning and teaching theories may be applied in the TIMSS findings.

The TIMSS team in South Africa were restricted by the Study Centre from modifying the international questionnaire to retain the compatibility of South African data with the international data capture framework, and by HEDCOM from entering into enquiries into issues that were likely to become 'sensitive'.

Although the questionnaire returns appear to show only occasional ambiguities, they also indicate major problems in some areas of South African education in Mathematics and Science, such as the curriculum content linked to applications of learning and teaching theory, the amount of practical work done and the amount of school time allocated to these subject focuses.

Opportunities to upgrade the attainment levels in Mathematics and Science are numerous. Arising out of this study and a number of recent South African internal programmes such as Project 2005 (Department of Education 1995 (g) and ongoing) and the development of 'outcomes' based curricula, 'attack points' - such as effective use of in-school time, curriculum revision, professional commitment and accountability - for reconstruction of education into an effective system are readily identifiable.

Willingness to approach these issues lies within the realms of Government at national level, within the will of local feeder communities and within the schools themselves: the principals and teachers. Last, but by no means least, the students, who currently appear to operate on a philosophy of entitlement, must be made to accept the fact that learning is acquired, not given or taken without commitment on their part. In other words, effective teaching and learning must become a collaborative venture. In Orton's words (1992:164):

> ... knowledge is not a transferable commodity and [one-way teacher to student] communication is not a vehicle for effecting its transfer. The teacher's role is to help the learner in the conceptual organization and reorganization of experience, but it is the learner who must do the conceptualizing.

7.3 THE OBJECTIVES OF THIS STUDY AS SET OUT IN CHAPTER 1

This study undertook to investigate a variety of objectives:

7.3.1 PERFORMANCE EXPECTATIONS IN THE TIMSS TEST ITEMS

OBJECTIVE 1

To provide a classification of the two hundred and eighty-six TIMSS questions (one hundred and fifty-one Mathematics and one hundred and thirty-five Science questions) into categories of expected performance.

The classification of questions into performance categories is displayed in Chapter 5, Tables 5.2 and 5.3. In both Mathematics and Science there are sufficient 'low concept' questions to have permitted a far higher level of achievement. The tables indicate that the differences between performance in 'higher' order questions and knowledge questions are insignificant.

7.3.2 PERFORMANCE IN QUESTIONS WITH SIMILAR CONTENT AREAS

OBJECTIVE 2 To examine performance in questions with similar content areas.

South African performances in questions dealing with similar and related areas are examined in some detail in Chapter 5. With the relatively few questions in which the South African scores were in excess of 50 per cent, the scores were so low as to render in-depth analysis of different average scores an almost fruitless exercise. From the results, there is ample evidence that South African students are lacking in the ability to grasp even basic concepts and problem solving skills in Mathematics and Science (see also 2.1.1).

7.3.3 PERFORMANCE IN SUB-FIELDS OF MATHEMATICS AND SCIENCE

OBJECTIVE 3 To analyse the achievement in the sub-divisions of Mathematics and Science fields of study.

Achievement in the various sub-divisions of Mathematics and Science are illustrated in Tables 5.9 to 5.12. Here, the evidence shows that there is no field of either Mathematics or Science in which South Africa excelled.

One rather ironical observation is that in almost every country, Chemistry was the lowest scoring section of Science. For no apparent reason, however, South Africa showed a smaller gap between Chemistry and the next lowest field of Science than other participating countries.

7.3.4 INCREMENT IN ACHIEVEMENT FROM THE LOWER GRADE TO THE UPPER GRADE

OBJECTIVE 4

To assess the variation of achievement between Standard 5 and Standard 6 students.

The significant finding in terms of this objective is that South Africa shows the lowest increase in achievement from Standard 5 to Standard 6 in both Mathematics and Science of all the participating countries. This observation supports the supposition made in Chapter 6 that the primary schools appear to be functioning more effectively than the secondary schools. However, in both cases, the achievement levels are exceedingly low. Comparison with the international increase in aggregate scores between grades makes this South African problem even more apparent. In paragraph 7.2.2 of this conclusion, attention is again drawn to the fact that the South African primary schools appear to be functioning more efficiently than the secondary schools at the junior secondary level.

The low difference in achievement shown in the table below occurs in spite of an extra year of teaching and despite the significantly improved curriculum fit. In fact, in South Africa's case, the curriculum fit for Mathematics increases from 58 per cent in Standard 5 to 80 per cent in Standard 6 and in the case of Science the fit increases from 18 per cent (in Standard 5) to 51 per cent (in Standard 6) as shown in Table 5.4.

Table 7.1 Comparison of differences in achieved scores (represented on the international scale) between Lower Grade and Upper Grade - Mathematics and Science

COUNTRY	MATHEMATICS			SCIENCE		
	LG	UG	Increase	LG	UG	Increase
South Africa	348	354	7	317	326	9
Thailand	495	522	27	493	525	32
Iran	401	428	27	436	470	34
Colombia	369	385	16	387	411	24
France	492	538	46	451	498	46
England	476	506	28	512	552	40
Czech Republic	523	564	40	533	574	41
Australia	498	530	32	504	545	41
United States	476	500	24	508	534	26

7.3.5 CURRICULUM 'FIT'

OBJECTIVE 5

To analyse the TIMSS question papers in terms of curriculum 'fit' and expected skills and knowledge performance.

Curriculum 'fit' has not turned out to be the spectre that it was anticipated to be. Accidental learning and the knowledge students bring to the classroom have been demonstrated to be a positive world-wide phenomenon which impacts on the TIMSS Mathematics and Science scores of all the nations beneficially. The South African problem is that students do not appear to know what they should have been taught. There are two aspects to the preceding statement. Firstly, the students do not appear to know what the curriculum for Grades 7 and 8 indicates that they should know and secondly, there is little certainty that they have been taught what they are expected to know in any effective manner to ensure sustained progress.

In Mathematics, despite the acceptable level of curriculum 'fit' between the question fields and what is taught in South Africa, the South African results show a general failure to achieve at even the levels of the other developing countries that participated in TIMSS.

There is a general failure to appreciate number value and sense as well as the processes to be followed to obtain answers to problems. This is a reflection of the two different approaches to the teaching of Mathematics and Science (see 2.1.1). Where the degree of curriculum 'fit' was relatively low, South African performances compared equally poorly in all aspects of Mathematics (Tables 5.9 and 5.10) and Science (Tables 5.11 and 5.12).

Even performance in those questions that lay within the South African curriculum content was disappointing. The table below shows that, perhaps contrary to expectations, for most participating countries, including South Africa, achievement between 'fit' and 'non-fit' items revealed relatively insignificant differences. Matching scores obtained between curriculum 'fit' items and 'non-fit' items suggests that there is very little difference in achievement between these two groups of items. For example, for curriculum 'fit' items (Upper Grade) the Russian Federation scored 62 per cent correct whereas for the all of the Mathematics items including the 'non-fit' items their students scored 60% correct.

In South Africa's case for Mathematics (Upper Grade) the score for 'fit' items was 23 per cent and for the whole test including 'non-fit' items the score was 24 per cenrt - a nearly unique reversal which shows that South African students scored marginally more at this level for questions on content they had not been taught (see also Chapter 5, Tables 5.9 to 5.12), as illustrated in the table below.

Table 7.2 Comparative differences in achievement between curriculum content items and those items which are not in national curricula

Country	Upper Grade			Lower Grade		
	In curriculum	Out of curriculum	Difference	In curriculum	Out of curriculum	Difference
South Africa	23%	24%	- 1%	24%%	23%%	+ 1%
Iran	38%	38%	0	32%	32%	0
Colombia	29%	29%	0	30%	24%	+ 6%
England	57%	53%	+4%	54%	47%	+ 7%
France	61%	61%	0	51%	51%	0
Singapore	79%	79%	0	74%	73%	+ 1%
Sweden	60%	56%	+ 4%	54%	47%	+ 7%
Russian Federation	62%	60%	+ 2%	55%	53%	+ 2%

This general TIMSS finding suggests that 'accidental' or 'extramural' learning has considerable significance to the overall process of education, which is possibly undervalued by education systems and serves to point out the importance that should be placed, in the classroom, on the prior knowledge that students bring to class with them (see discussion of prior knowledge in 2.1.4.2). Research into how students gain access to this 'accidental' knowledge would be of value to teachers and to education administrators.

7.3.6 THE IMPACT OF LANGUAGE OF TESTING ON ACHIEVEMENT

OBJECTIVE 6

To investigate the impact of second language on achievement.

Language problems have been discussed at some length in Chapter 6 of this study. As pointed out, South Africa had by far the largest proportion (almost 80 per cent) of its students writing in a second or even third language. There can be no doubt that language exerts a considerable influence on performance. Barry (1996) explains the difference between communicative language and technical language (the language of the questionnaires and the test papers respectively). Whilst students may handle communicative language satisfactorily, there are additional, more specific cognitive problems associated with technical language. Pretorius (1997: 2) introduces the distinction between 'reading' books and 'absorbing' books which corresponds to the more modern distinction between the 'decoding' and the 'comprehension' of the written word. She continues by noting that at the turn of the century the medical educator and philosopher, Sir William Osler, humorously remarked, 'Its easier to buy books than to read them, and easier to read them than to absorb them' (cited in Daneman, 1991: 532). The distinction that Osler (*ibid.*) makes between 'reading' and 'absorbing' books corresponds to some extent to the distinction between 'decoding' and 'comprehension':

> Decoding refers to the oculomotor, perceptual and parsing aspects of reading activity whereby written signs are translated into language, while comprehension refers to the understanding process whereby meaning is assigned to the whole text.

Concepts and allusions are interpolated into the text without specific reference being made to fine detail. For example, an 'atom' may be referred to in the flow of text assuming the readers' intellectual mastery of the concept.

If a textbook (or class notes) cannot be properly understood, learning cannot take place. And, this is particularly true of Mathematics and Science texts which are usually conceptually dense and therefore often require more than one reading to access the content. There is no doubt that, for most South African students, there is a hiatus between decoding (reading) a class text and understanding its meaning. Perfetti (1988: 119) sums up this dilemma very elegantly:

> ... comprehension suffers if the decoding process takes up too much of the limited resources [of the reader].

In second language teaching and learning situations, the patent limitations are both in the mastery level of the teacher and the comprehension level of the student and this is virtually irrespective of the subject or the content. In teaching and learning theory, teachers should, but seldom do, pay attention in their teaching to new vocabulary. Whilst Pretorius (1997: 12) claims that increased vocabulary is not necessarily indicative of increased comprehension levels, the TIMSS style of short (few words) questions facilitates correct answers if the 'technical' words are comprehended without significant effort. Olson, Duffy and Mack (1984) in Pretorius (1997: 18) make the point that:

> ... the analysis of cognitive processes in real time is one of the most methodologically difficult tasks in all of [cognitive] psychology. The events which we wish to examine are internal to the mind, with only occasional external correlates. Further, most cognitive tasks involve a lot of hierarchically interrelated sub-components, [most] likely operating in parallel ... and yet ... a deep understanding of how to access the readability of text and how to remedy reading [and comprehending] difficulties will require the analysis of the process of cognition.

While there are many possible solutions to the reading and comprehension problems faced by second language students, much remains to be fully understood and remedied.

Appendix 5 provides a graphic analysis, in support of the discussion in Chapter 6, of the relationship between achievement and the use of the languages of testing in the home. These analyses, presented on a provincial basis, suggest that whilst there was an indubitable difficulty placed on students writing the TIMSS tests in a language other than their home language, this problem may, to some extent, have been exaggerated by earlier researchers (see Odendaal, 1985, Basel, 1995, and Barry, 1996). Alternatively, and more hopefully, the problem of language is already being addressed by the education system.

7.3.7 GENDER DIFFERENCES IN ACHIEVEMENT

OBJECTIVE 7 To examine gender differences in achievement.

Internationally there is a trend, as would be expected, that boys out-perform girls in the large majority of countries. The TIMSS test instruments found that, in Science, the only country in which girls achieved better than the boys is Thailand and this was only in the Lower Grade. At the Upper Grade, boys consistently out-performed girls in Science in all countries. In South Africa, the difference is, however, of little or no import. In each of the sub-divisions of Science this trend continues, but is nowhere of statistical significance. The overall gap between genders in Science achievement from Lower Grade to Upper Grade decreases from twenty-one points to eleven points.

In the case of Mathematics, Lower Grade, one fifth of the countries show girls out-performing boys but there is no statistical significance in any these differences. At the Upper Grade the gap widens. In only five of the countries do girls out-perform boys. The South African sample again shows that there is no field of Mathematics where the girls score higher than the boys. However, at the Upper grade level the gap narrows from eleven points to eight points.

Considering the small majority of girls over boys in the South African sample, it would appear that at the end of Standard 6 [Grade 8] the boys and the girls in these classes start off on an equal footing in these subject fields.

7.4 THE PREMISES EXAMINED IN THIS STUDY AS SET OUT IN CHAPTER 1

This thesis sought to explore four fundamental premises:

7.4.1 PREMISE 1: SOUTH AFRICAN STUDENTS ARE NOT ACHIEVING TO SATISFACTORY STANDARDS

> PREMISE 1
>
> The South African education system may not be educating students in Mathematics and Science to the achievement standards of other developing countries that participated in TIMSS.

The TIMSS study corroborated this premise as shown in this thesis. The South African performance did not match up to the performance of other developing nations that participated in TIMSS. However, on a more optimistic note, South Africa was the only African country that was able to participate and complete the programme to acceptable levels. Only forty-two nations were able to meet the requirements; another eleven countries were unable to complete the process and others dropped out along the way. Reasons for failure to satisfy the international Study Centre requirements included:

- failure to satisfy one or more of the guidelines;
- failure to reach the required sample participation rate;
- failure to meet the age/grade specifications; and
- failure to satisfy class/classroom sampling procedures.

It is worth noting again that Mexico withdrew its findings from any aspect of the international reporting at a very late stage. The reasons have not been stated and are subject to speculation.

7.4.2 PREMISE 2: PREVIOUS IEA FINDINGS HAVE LIMITED APPLICATION TO SOUTH AFRICA

> PREMISE 2
>
> A number of the findings of previous IEA Studies may not be valid for the South African situation.

South Africa is a developing nation and, at the time of the TIMSS testing programme, was in a state of considerable internal socio-political turmoil. Whilst acknowledging that 'black' education had been used aggressively as a political tool for social control, it had, from its own internal frustration, been in a state of turmoil since the 1976 Soweto uprisings. Furthermore, the slogan 'revolution before education' had had considerable influence on all levels of the education system. Twenty years of unrest and political confrontation have polarized a large part of the student population to the extent that, paradoxically, they still appear to be bound to the process of revolution and have lost sight of its aims.

South Africa has only marginal facilities available to undertake a study such as TIMSS which is substantially First World oriented in terms of resources and particularly communications. South African grade/age levels are somewhat different from those of the more developed countries and educational resources are available on a very different scale. The details of these findings are dealt with in some detail in 7.5 below.

7.4.3 PREMISE 3: SOUTH AFRICAN CURRICULA

> PREMISE 3
>
> That South African Science curricula do not appear to be 'in step' with other international curricula.

The matter of curricula has been dealt with both in Chapter 4 and earlier in this concluding chapter. It appears that in the case of Mathematics the curriculum 'fit' is well within the range of the fit of most countries whereas the Science curriculum 'fit' is rather poorer than the curriculum 'fit' of the other participating countries. The current revisions taking place in South African curricula, it is hoped, will serve to bring local curricula more into line with those of other nations that participated in TIMSS whilst rightfully retaining their own indigenous characteristics.

7.4.4 PREMISE 4: PROBLEM SOLVING SKILLS

> PREMISE 4
>
> That problem solving skills are not a readily available part of South African students' intellectual resources.

Analysis of the test instrument findings in Chapter 5 reveals that South African school students do not have adequate or even the expected levels of problem solving skills as displayed by the overall low achievement levels (see also discussion in 2.1.1).

7.5 FINDINGS FROM PREVIOUS IEA INTERNATIONAL STUDIES

The major findings of previous IEA Studies as they apply to Mathematics and Science education are listed below in some detail since these findings form a 'test-bed' against which South African achievement can be measured. These findings are largely extracted from *The World of School Learning* (Keeves, 1994). They fall into two main categories, viz. general findings and the results from two past specialist Science Studies.

7.5.1 MORE DEVELOPED COUNTRIES ACHIEVE AT A HIGHER LEVEL THAN THE LESS DEVELOPED COUNTRIES

> Research Finding 1 (Keeves, 1994: 3)
>
> There are marked differences in average levels of achievement between the students in school in the More Developed Countries (MDC) and those in the Less Developed Countries (LDC). This occurs in spite of the fact that in the Less Developed Countries significantly fewer than 100% of the relevant age groups are enrolled at school.

There were only four developing countries that completed the TIMSS cycle of testing and presentation of data to the Study Centre. Of these countries (South Africa, Iran, Colombia and Thailand) all, with the exception of Thailand, performed relatively poorly. Insofar as high achievements are concerned Thailand indicated, by its achievements, its readiness to join the traditional high achieving oriental countries: Japan, Korea, Hong Kong and Singapore.

From this analysis of the TIMSS data, this research finding proposed by Keeves can be supported with few reservations. The statement of findings quoted above must be applied to TIMSS with reservations based on the grounds that so few of the worlds Less Developed Countries were able to participate in

TIMSS. No international school enrolment figures are as yet available but it appears that three of the less developed countries fill the lowest niches in the international ranking tables and do not have the full eligible population enroled in school. This observation pertains to both Mathematics and Science achievement.

7.5.2 ACHIEVEMENT IS RELATED TO INSTRUCTIONAL TIME

> **Research Finding 4** (Keeves, 1995: 9)
> Student achievement in Mathematics and Science is directly related to the instructional time given to these subjects.

Whereas it cannot as yet be deduced directly from of this study, it is safe to surmise that a timetable allocation of one and a half hours to two hours per week for Science and two hours per week for Mathematics in South African schools, compared to four to six hours per week in the higher achieving countries testifies to the validity of this research finding.

The most significant factor though is that achievement is proportional to time spent on a subject. In broader terms, achievement relates to the number of school days in an academic year and to the number of effective hours of instruction and learning; areas in which South Africa patently has serious problems, as discussed in Chapter 4.

7.5.3 HOMEWORK

> **Research Finding 5** (Keeves, 1995: 11)
>
> After all other factors relating to achievement have been taken into account, achievement is related to the amount of time spent on homework (and other extramural Scientific and Mathematical activity).

The analysis of the returns from the student questionnaire analysed in Chapter 6 reveals that South African students do not meet the homework requirements that students from the higher achieving countries are expected to accomplish.

7.5.4 CURRICULUM DESIGN AND MANAGEMENT

> **Research Finding 6** (Keeves, 1995: 13)
>
> Achievement is related to opportunities to learn. The content and skills considered important for students to learn must be identified by curriculum developers, and students MUST be provided with appropriate opportunities to learn those content and skill attributes. It is important to note that the less developed the education system, the greater the care that should go into curriculum planning.

The TIMSS curriculum analysis and curriculum matching processes demonstrated that South African curricula for Science is substantially out of step with those of most of the other TIMSS participants. Despite these discrepancies the TIMSS findings show that curriculum fit is a relatively minor component in terms of achievement. Moreover, the problems of the curriculum content appear to be compounded by the limited time allocated to these subjects, as already noted in 7.5.2 and 7.5.3, above, and the fact that teachers of South African middle school classes, that is, at junior secondary level, do not seem to have adequate mastery of subject content.

7.5.5 READING MATTER IN THE HOME

> Research Finding 8 (Keeves, 1995: 17)
>
> The level of reading materials in the home correlated significantly with achievement. It appears that general opportunities to read assist the student in learning more specialized material.

The rank order correlations calculated in Chapter 6 demonstrate that this correlation shows, at best, a weak connection for a number of extraneous reasons discussed in Chapter 6. Elley (1992) claims that good reading facilities in the schools show a higher correlation with high achievement. The claims made by Pretorius (1997) that poor readers are not encouraged to read and poor readers cannot comprehend what they do read none the less underlines the problem of disadvantaged students not receiving the 'home' support they need. International data concerning within country correlations between books in the home and achievement are not, as yet, available.

7.5.6 SOCIO-ECONOMIC STATUS AND ACHIEVEMENT

> Research Finding 9 (Keeves, 1995: 19)
>
> Socio-economic status and position correlates positively with achievement.

The correlations made between national wealth and achievement (Chapter1) bear testimony to the validity of this observation. Poor countries appear to achieve poorly, thus enshrining their poverty on a cycle that has no apparent exit into a line of success. However, as already noted, Thailand has managed to obviate this poverty barrier and its increasing prosperity can be linked to increasing education achievement.

7.5.7 GENDER BASED ACHIEVEMENT

> Research Finding 11 (Keeves, 1995: 23)
> There is a significant difference between achievement which is based on gender.

In South Africa there is no direct link between achievement and gender. The gender differences in both Mathematics and Science, discussed earlier, are of no statistical significance. Internationally, several countries - Hong Kong and New Zealand (UG Science), Korea and England (LG Science) and to a somewhat lesser extent, Hong Kong and Korea (UG Mathematics), and England and Israel (LG Mathematics) - did, however, record significant differences in the achievement of boys over girls.

7.5.8 FINDINGS FROM IEA SPECIALIST STUDIES

7.5.8.1 Influence of practical work on achievement

> Research Findings from Specialist IEA Study 3. The First IEA Science Study
>
> There was no clear evidence to show that the extent of the students' practical experience was related to a higher level of achievement in science as measured against more theoretical tests.

South Africa was not able to participate in the performance (practical) aspects of TIMSS therefore there is no pertinent comment to make on this finding.

7.5.8.2 The level of experience and interest of teachers

> Research Finding from Study 11. The Second Science Study
>
> The general level of experience, scientific training and interest of the teachers influenced the level of achievement of their students.

As was pointed out in Chapter 6, when students' responses on the pedagogic techniques used by their teachers were discussed, there appears to be a paradox between the class teachers' methodologies and the low level of achievement. The relative disinterest shown by teachers as recorded by Jansen (1993), Maja (1994 and 1995) and Bateson (1994) is amply reflected by the low national student achievement. A paraphrase of Alistair Cooke's (1997) comment on the American TIMSS findings is equally applicable to South Africa:

> For ... years the [South African] public and teachers have had low expectations of the students and the schooling system and the students have faithfully met those expectations.

7.6 SIGNIFICANT FINDINGS ARISING FROM THE TIMSS - SOUTH AFRICA STUDY

7.6.1 UNIVERSAL MISCONCEPTS

TIMSS serves admirably to underline the international existence of misconcepts. Many of the misconcepts offered to the students as distracters were selected as answers. The prevalence of misconcepts shown in the results of all the participating countries is discussed in Chapter 5. It is from this type of analysis that real value to teachers can be gained from an analysis of the TIMSS information resource. Correctly handled, TIMSS offers a guide to teachers and education students as to where to place emphases and how to establish clarity and understanding in their teaching and learning programmes.

7.6.2 OTHER SOUTH AFRICAN INVESTIGATIONS THAT CORROBORATE THE TIMSS FINDINGS

Bateson, of the University of British Columbia, Vancouver, was commissioned to carry out evaluations of the South African Centre for the Advancement of Science and Mathematics Education ([CASME] 1994) at the University of Natal, Durban, the Science Education Project ([SEP] 1995) and of the Primary Science Project ([PSP] - commissioned in 1996 and as yet incomplete) and it is of interest to compare the findings of these independent evaluative studies with the findings of TIMSS. Indeed the interest has developed to the point where the PSP findings will be merged with the South African National TIMSS findings, when the former evaluation is completed and reported on.

7.6.2.1 The Centre for the Advancement of Science and Mathematics Education (CASME) evaluation

Bateson (1994: 1) opens his discussion of CASME with the words:

> There is no doubt that CASME has had a very profound, positive influence on Science and Mathematics education in Kwa-Zulu-Natal.

In the opening paragraphs Bateson provides a description of the Styx River secondary school which tallies very closely with Maja's description of the 'Harry Gwala' School (1995). In Bateson's introduction the Styx River School is described as:

> We step over the sill of the entrance to the concrete block staff/administration building at the bottom of the "U" and proceed about four metres down a dark, tight corridor with an uneven dirt floor until coming to an asymmetric hole in the left wall which has been roughly smashed out with a sledge hammer. Cautiously easing through the ragged hole, we enter the principal's office: a room with walls of graffiti-decorated concrete blocks, one window with no glass remaining, a loose dirt floor, and only three quarters of the corrugated steel roof still in place.
>
> Inside a classroom, the once smooth concrete floor is pocked with holes and strewn with loose gravel from the disintegrating material.

The Biology lesson described consists of the teacher reading directly from a textbook. The lesson topic is read and then the appended questions are read for the class to answer. Bateson continues:

> This particular teacher of Biology is not trained to teach [any] Science, did not take any Science content or method courses in the three years at the Teacher Training College he attended.

In a similar manner to Maja, Bateson (*ibid.*) describes the school in process. At 09.30 with students and teachers still arriving no teaching is taking place. He continues to describe how the teachers all left the school soon after to cash their monthly pay cheques - a school day without teaching or learning taking place.

Maja (1995: 28-29) describes the 'Harry Gwala' school in the following terms:

> Most windows are intact except four or five which are broken; the classroom doors have not been removed, although 10 of them have had their handles removed or broken. Four classrooms had their doors removed in 1994 and the pupils consequently stopped using them. They were unused, not only because of the cold weather, but mainly because boys from the surrounding location turned them into 'hang-around' centres in the evenings and left

> them dirty by making fires with the desks and relieving themselves.
>
> All the classrooms have blackboards, though 15 [out of 28] of them are not in good condition. The toilets are blocked and too dirty for the pupils to use. Graffiti can be seen on the walls, including inside the principal's office. There were five break-ins in 1994 with chairs and stationery being the main items stolen.

Maja and Bateson's descriptions of an urban and a rural school respectively coincide almost to the point of collusion. As can be seen from these descriptions, a number of South African schools provide a teaching and learning environment which is not conducive to either.

7.6.2.2 The Science Education Project evaluation

As a component of this evaluation Bateson (1994) made use of a Canadian Science achievement survey test instrument and applied it to SEP schools and to an equal number of non-SEP schools. This achievement test, derived from a battery of Canadian Grade 9 questions and applied to Standard 7 classes in South Africa, presented results which were conformable in all respects with the South African TIMSS findings. The SEP schools (twenty-five schools and a population of 2 829 students) averaged 33% in the performance items in the Canadian test which is very close to the range of the South African TIMSS scores.

7.6.2.3 The PSP evaluation

Unfortunately this evaluation study is not yet complete in a final report form. The PSP schools in the national TIMSS sample (twenty-four schools) were extracted from the national TIMSS data base and performances compared between TIMSS outcomes and the results obtained from modified Canadian tests that Bateson used. Bateson's comment (PSP, 1996) was that 'the two sets of results are to all intents and purposes congruent'.

These three independent studies tend to confirm the findings of TIMSS both qualitatively and quantitatively. These three reports and the TIMSS findings describe an education system that is, by and large, in urgent need of restructuring and a change in educational approach towards achievement.

7.7 THE TEST - CURRICULUM MATCHING ANALYSIS

One of the defences that has been proffered for South Africa's poor performance in TIMSS was the large proportion of items lying outside the domestic curriculum. This defence, however, is questionable in the international context. Table 7.2 earlier in this chapter and the examples quoted below suggest that the difference in scores between curriculum 'fit' items and 'non-fit' items was minimal in nearly all cases.

Beaton *et al.* (TIMSS., (1996, (h and i) Appendix B: 5) make the point that :

> It is clear that the selection of items, [as curriculum 'fit' items] does not have a major effect on the general relationship among the countries. Countries that had substantially higher or lower performance on the overall tests in comparison to each other also had higher or lower relative performance on the different sets of items ....

For example, in the case of Mathematics - Upper Grade, the four top performing countries had, on the test as a whole and on all the different sets of items, high achievement levels. At the Mathematics - Lower Grade and in both the Science grades the same feature is observed. These levels of achievement, though, can only have application where there is already general agreement on the suitability of the selected question fields and the actual questions set.

7.8 THE VALUE OF INTERNATIONAL STUDIES OF ACHIEVEMENT

As postulated in Chapter 1, TIMSS has provided a national view of Mathematics and Science education which has not been available before. Many of the generally held opinions concerning education in these subject fields were based on experience, mythology, anecdote, opinion and political positioning. A number of these 'prejudices' have now been confirmed in a scientific manner.

7.9 CLOSING COMMENT

Whilst being the National Research Co-ordinator for the TIMSS study in South Africa has been a tremendous challenge, it has also been a stimulating adventure.

In retrospect, after more than three years of sustained effort, the problems and priorities of South African education can, to some extent, be identified and prioritized.

Firstly, there is the problem of 'time on task' which, as already intimated is clearly insufficient for subjects such as Mathematics and Science with their loading of higher order concepts and self-discipline requirements. 'Time on task' relates to:

- the length of the school year (too few school days);
- the characteristic 'short days';
- lessons that do not take place, thus shortening the school day; and
- late arrivals and early departures from school by students and teachers.

The above are all factors which serve to identify a critical lack of professionalism and commitment in teaching.

The problem of making schools effective in terms of time cannot be allocated to any particular stakeholder in education. It is the responsibility of Government, Education Departments, School Management Councils, teachers, students and their parents alike. No person or body with a stake in education is exempt from this responsibility. Maja (1995: 12) cites sources that claim that 'teachers are the greatest agents of change'. From the findings of this thesis, this has patently not been the case in South Africa because a substantial proportion of teachers teaching Mathematics and Science are often poorly trained in these subjects. Some lack incentive to 'prepare lessons' and are unwilling to or incapable of exercising discipline in their classes.

It is serious enough to reiterate that within school timetables, South African students are receiving far less time allocated to Mathematics and Science (approximately ninety minutes to two hours per week) than 'more successful' countries (four to six hours per week). Even this minimal time is often expended fruitlessly because of missed lessons, lessons not taught and timetables not functioning at the beginning of the school year. Other 'arbitrary' exercises such as sports and fund-raising activities also militate against effective teaching. Maja (1995: 45) quotes the 'Harry Gwala' School as halting the process of education for a month while 'fund-raising' activities were conducted. The same school ceased to function while a football team was in competition. 'It was deemed unfair to teach some students while the "team" were either playing or training'.

Secondly, the impact of learning through the medium of a second language cannot be over stressed, particularly when the teachers' themselves do not have an adequate mastery of that language. Transmitting information in another language (usually the teacher's first language) occurs frequently and is yet another negative factor since in the 'rainbow nation' there will inevitably be a majority of students who may not share the teacher's mother tongue.

> At this school, if you don't know Shangaan, you will never come right. (Maja 1995: 45)

Thus there is a potentially anomalous situation where the students pay penalties for not having mastery of the language of instruction (English) and they may also be penalized for not being proficient in the language of the teacher.

There is no disputing the issue discussed by Jones (1997: 2) where he poses the questions:

1. (3 x 5) + (4 x 8) = ?
2. John's mother has asked him to go to the store to buy three apples and four oranges. If apples cost 5 cents each and oranges cost 8 cents each, how much money should John take with him to the store?

Both questions require the same arithmetic skills. However, question 2, in addition to testing arithmetic ability, also tests the ability of the student to read and the ability of a student to extract and organize appropriate mathematical information from a paragraph of text.

The results from the TIMSS Mathematics questions demonstrate that many of South Africa's Grades 7 and 8 students cannot answer questions similar to Question 1 above, let alone decipher the words to identify a mathematical process and complete similar questions correctly. For example Question L17 is as follows:

> What is the value of 2/3 - 1/4 - 1/12?

and Question P14 is as follows

> Mary and Jane and their mother were eating a cake. Jane ate 1/2 of the cake. Mary ate 1/4 of the cake. Their mother ate 1/4 of the cake. How much of the cake is left?

Both questions have the same mathematical expectations, that is to add 3 fractions. In the case of Question L17, 16% (LG) and 16.9% (UG) of South African students indicated the correct answer. In the case of P 14, 18.4%(LG) and 23.1%(UG) scored the mark for the correct answer.

The national South African TIMSS returns themselves are, to some extent, enigmatic about the impact of language problems on achievement. There are few clear indicators that identify the problem and its magnitude. Certainly there are internal indications (such as the 'congruence between Upper Grade and Lower Grade responses to relatively complex questions), in the student questionnaire data, that the language comprehension of the respondents was adequate. It is intended for the second round of TIMSS to implement a Science contextualized language mastery test and thereby to investigate the impact of language problems on Mathematics and Science learning problems.

The third major issue of concern in South African schools, that TIMSS did not enquire into, lies in the substantial level of 'migrant' students who move whimsical from school to school for a large number of spurious reasons.

Fourthly, there is the politicization of schools where it interferes with the learning process, polarizes and splits the teacher corps and renders any efforts to educate ineffective.

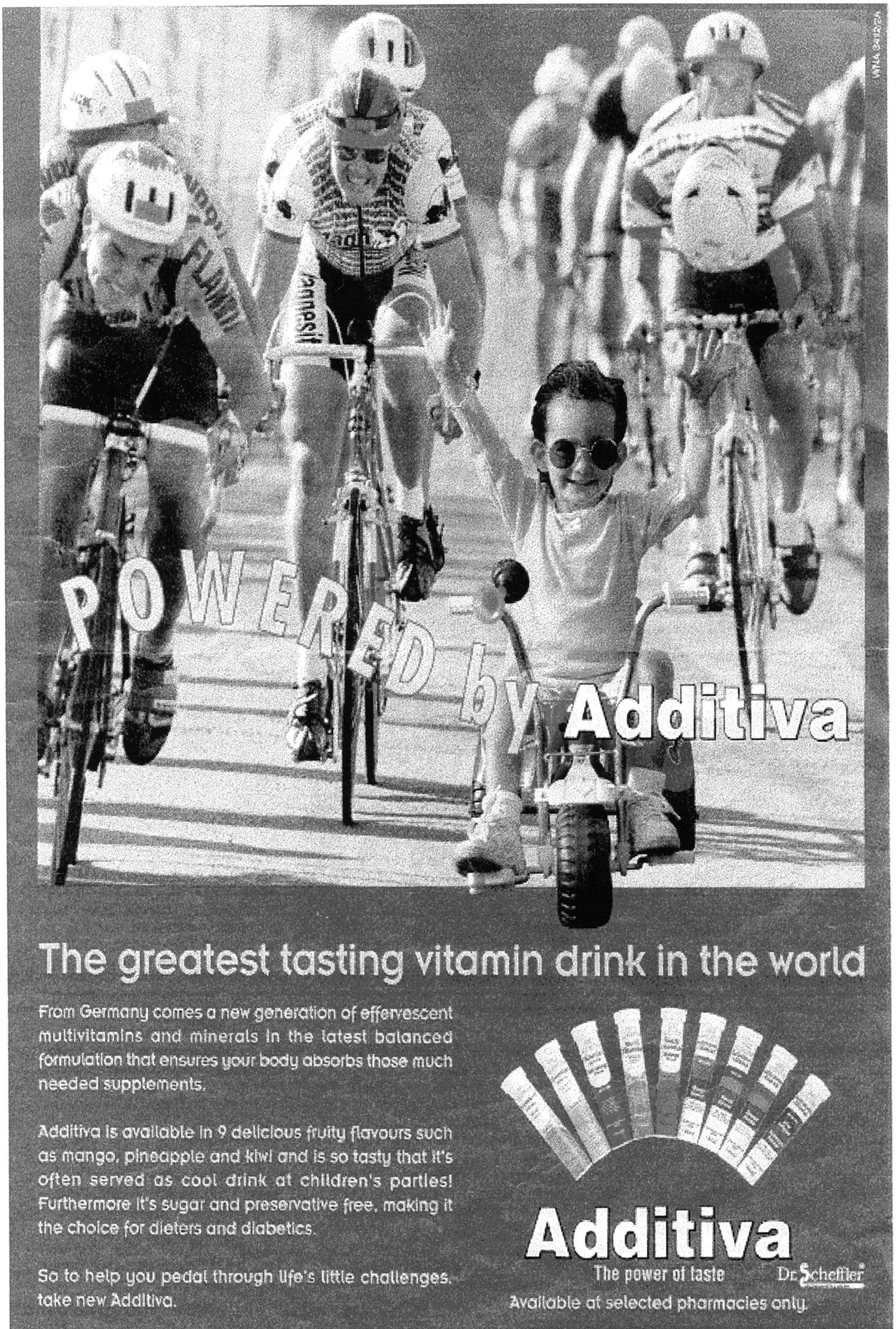
Fifthly, South African curricula still retain all the essentials that caused criticism fifteen years ago in the 'de Lange' commission reports (Human Sciences Research Council, 1981 [Vol. 13]). South African curricula are too academic, non-relevant and too rigid for the majority of students and, it seems, for their teachers as well.

Sixthly, in harsh economic terms, the very substantial investment in education made by South Africa is not realizing justifiable returns.

Finally there appears to be a virtual lack of realization and appreciation of the fact that learning is a co-operative process in the classroom. The partners in this process are the teacher and the student. Lochhead (1985, quoted in Orton, 1992: 163) summarizes this attitude precisely:

> What I see as critical to the new cognitive science is the recognition that knowledge is not an entity which can be simply transferred from those who have [the teacher] to those who don't [the student] .... Knowledge is something which each individual learner must construct for and by himself [in the context of the classroom and the teacher].

Studies of the TIMSS type, as described in this thesis and in which the status of Mathematics and Science knowledge and skills is analysed and evaluated, should become a main component of a more wide ranging longitudinal survey of achievement in Mathematics and Science using both TIMSS and HSRC generated test materials. Achievement measures should also be applied to language mastery in a Mathematics and Science based context. A longitudinal survey would be able to generate an image of scholastic performance, trends and effects of changes on achievements on a national basis for a medium term period which will be of considerable value to Education Administrators, Planners and other interest groups and stake holders.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APPENDIX 2. DETAILED MATHEMATICS FRAMEWORK CATEGORIES

1. CONTENT

1.1 NUMBERS

1.1.1 WHOLE NUMBERS

1.1.1.1 Meaning, (the uses of numbers, place value and numeration, ordering comparing numbers.

1.1.1.2 Operations (addition, subtraction, multiplication, division, mixed operations)

1.1.1.3 Properties of operations (communicative property, distributive property, etc.)

1.1.2 FRACTIONS AND DECIMALS

1.1.2.1 Common fractions (meaning and representation of common fractions and mixed numbers

1.1.2.2 Decimal fractions (meaning and representation of decimals, computations and mixed numbers)

1.1.2.3 Relationships of common and decimal fractions (conversion to equivalent forms, ordering of fractions and decimals

1.1.2.4 Percentages (all work with percent computations and various types of percent problems)

1.1.2.5 Properties of common and decimal fractions (communicative, distributive etc.)

1.1.3 INTEGER, RATIONAL AND REAL NUMBERS

1.1.3.1 Negative numbers, integers and their properties

1.1.3.2 Rational numbers and their properties

1.1.3.3 Real numbers, their sub-sets and their properties

1.1.4 OTHER NUMBERS AND NUMBER CONCEPTS

1.1.4.1 Binary arithmetic and/or the number bases

1.1.4.2 Exponents, roots and radicals (integer, rational and real exponents)

1.1.4.3 Complex numbers and their properties

1.1.4.4 Number theory (primes and factorization, elementary number theory etc.)

1.1.4.5 Counting (permutations and combinations etc.)

1.1.5 ESTIMATION AND NUMBER SENSE

1.1.5.1 Estimating quantity and size

1.1.5.2 Rounding and significant figures

1.1.5.3 Estimating computations (mental arithmetic and reasonableness of results)

1.1.5.4 Exponents and orders of magnitude

1.2 MEASUREMENT

1.2.1 UNITS - (concept of measure and standard units (including the metric system), use of appropriate instruments (precision and accuracy), common measures (length, area, volume, capacity, time and the calendar, money, temperature, mass and weighing, angles, quotients and products of units, km/h, m/s etc.), dimensional analysis.

1.2.2 PERIMETER, AREA, AND VOLUME (concepts of perimeter, area, ace area, volume, formulae for perimeters, areas, surface areas, and volumes)

1.2.3 ESTIMATION AND ERRORS (estimation of measurements and errors of measurement, precision and accuracy of measurements)

1.3 GEOMETRY: **position, visualization and shape**

1.3.1 TWO-DIMENSIONAL GEOMETRY: CO-ORDINATE GEOMETRY (line and co-ordinate graphs, equations of line in the plane, conic sections and their equations)

1.3.2 TWO DIMENSIONAL GEOMETRY : BASICS (points, lines, segments, rays, angles, parallelism, and perpendicularity)

1.3.3 TWO-DIMENSIONAL GEOMETRY: POLYGONS AND CIRCLES (Triangles quadrilaterals: their classification and properties, Pythagorean Theorem and applications, other polygons, circles and their properties)

1.3.4 THREE DIMENSIONAL GEOMETRY (three dimensional shapes and surfaces and their properties, planes and lines in space, spatial perception and visualization, co-ordinate systems in three dimensions, equations of lines, planes and surfaces in space)

1.3.5 VECTORS

1.4 GEOMETRY: **symmetry, congruence, and similarity**

1.4.1 TRANSFORMATIONS (patterns, tessellation's, friezes,) stencils etc., symmetry in three dimensions, symmetry in algebra and number patterns,) transformations, symmetries and congruence, enlargements, (deletions), combinations of geometric transformations, group structure of transformations, matrix representation of transformations)

1.4.2 CONGRUENCE AND SIMILARITY (congruencies(congruent triangles and their properties, SSS, SAS), congruent quadrilaterals and polygons and their properties, similarities (similar triangles and their properties)

1.4.3 CONSTRUCTIONS USING STRAIGHT EDGE AND COMPASS

1.5 PROPORTIONALITY

1.5.1 PROPORTIONALITY CONCEPTS (meaning of ratio and proportion, direct and inverse proportion)

1.5.2 PROPORTIONALITY PROBLEMS (solving proportional equations, solving practical problems with proportionality, scales(maps and plans) proportions based on similarity

1.5.3 SLOPE AND TRIGONOMETRY (slope and gradient in straight-line graphs, trigonometry of right-angled triangles)

1.5.4 LINEAR INTERPRETATION AND EXTRAPOLATION

1.6 FUNCTIONS: **relations and equations**

1.6.1 PATTERNS, RELATIONS AND FUNCTIONS (number patterns, relations and their properties, functions and their properties, representation of relations and functions, families of functions (graphs and properties), operations on functions, related functions (inverse and derivative etc.), relationship of functions and equations (e.g. zeros of functions as roots of equations), interpretation of functions graphs, * functions of several variables, recursions)

1.6.2 EQUATIONS AND FORMULAS (representation of numerical situations, informal solution of simple equations, operations with expressions, equivalent expressions (factorization and simplification), linear equations and their formal (closed) solutions, quadratic equations and their formal (closed) solutions, polynomial equations and their solutions, trigonometrical equations and identities, logarithmic and exponential equations and their solutions, solution of equations reducing to quadratics, radical equations, absolute value equations, etc. other solution methods for equations (e.g. successive approximation), inequalities and their graphical representation, systems of equations and their solutions (including matrix solutions), systems of inequalities, substituting into or rearranging formulas, the general equation of the second degree)

1.7 DATA REPRESENTATION, probability and statistics

1.7.1 DATA REPRESENTATION AND ANALYSIS (collecting data from experiments and simple surveys, representing data, interpreting tables, charts, plots and graphs, kinds of scales (nominal, ordinal interval and ratio), measures of central tendency, measures of dispersion, sampling, randomness and bias, prediction and inferences from data, fitting lines and curves to data, correlation's and other measures of relations, use and misuse of statistics)

1.7.2 UNCERTAINTY AND PROBABILITY (informal likelihood's and the vocabulary of likelihood's, numerical probability and probability models, counting principles, mutually exclusive events, conditional probability and independent events Bayes' Theorem, contingency tables, probability distributions for discrete random variables, probability distributions for continuous random variables, expectation, sampling, estimation of population parameters, hypothesis testing, confidence intervals, bivariate distributions, Markov processes, Monte Carlo methods and computer simulations)

1.8 ELEMENTARY ANALYSIS

1.8.1 INFINITE PROCESSES (arithmetic and geometric sequences, arithmetic and geometric series, Binomial Theorem, other sequences and series, limits and convergence of functions, continuity)

1.8.2 CHANGE (growth and decay, differentiation, integration, differential equations, partial differentiation)

1.9 VALIDATION and structure

1.9.1 VALIDATION AND STRUCTURE (logical connectives, quantifiers ("for all," "there exists"), Boolean algebra and truth tables, conditional statements, equivalence of statements (including converse, contrapositive and inverse statements), inference schemes, (e.g. modus, ponens, modus tollens), direct deductive proofs, indirect proofs and proof by contradiction, proof by induction, consistency and independence of axiom systems)

1.9.2 STRUCTURING AND ABSTRACTING (sets, set notation and set combinations, equivalence relations, partitions and classes, groups, fields, linear (vector) spaces, sub-groups, sub-spaces etc., other axiomatic systems (e.g. finite geometries)).

1.10 OTHER CONTENT

1.10.1 INFORMATICS (operation of computers, flow charts, learning a programming language, programs, algorithms with applications to the computer, complexity, history and nature of mathematics, special applications of mathematics (kinematics, Newtonian mechanics, population growth - discrete or continuous models, networks - applications of graph theory, linear programming, critical path analysis, examples from economics), problem solving heuristics, non-mathematical science content, non-mathematical content other than science)

2. PERFORMANCE EXPECTATIONS

2.1 KNOWING

2.1.1 REPRESENTING (demonstrating knowledge of a non-verbal mathematical representation of a mathematical object or procedure either by selection or by construction, either by selection or by construction, either formal or informal representations might be concrete, pictorial, graphical. algebraic, etc.)

2.1.2 RECOGNIZING EQUIVALENTS (selecting or constructing mathematically equivalent objects (e.g. equivalent common and decimal fractions, equivalent representation of concepts - e.g. place value, equivalent axiomatic systems, etc.)

2.1.3 RECALLING MATHEMATICAL OBJECTS AND PROPERTIES (fitting given conditions)

2.2 USING ROUTINE PROCEDURES

2.2.1 USING EQUIPMENT (using instruments, using calculators and computers)

2.2.2 PERFORMING ROUTINE PROCEDURES (counting and routine computations, graphing, transforming one mathematical object into another by some formal process, e.g. multiplying by a matrix, measuring)

2.2.3 USING MORE COMPLEX PROCEDURES (estimating to arrive at an approximate answer to a question, collecting, organizing, displaying or otherwise using quantitative data, comparing and contrasting two mathematical objects, quantities, representations, etc., classifying objects or working with the properties underlying a classification system)

2.3 INVESTIGATING AND PROBLEM SOLVING

2.3.1 FORMULATING AND CLARIFYING PROBLEMS AND SITUATIONS (formulate or clarify a problem related to a real world or other concrete situation)

2.3.2 DEVELOPING STRATEGY DEVELOPING STRATEGY (develop a problem-solving strategy or data gathering experiment and discuss that strategy or experiment (not just applying the strategy or carrying out the experiment))

2.3.3 SOLVING (execute some known or *ad hoc* solution strategy)

2.3.4 PREDICTING (specify an outcome (number, pattern etc.) that will result from some operation or experiment before it is actually performed)

2.3.5 VERIFYING (determine the correctness of the result of problem solving: interpret results in terms of an initial problem situation to evaluate how sensible the results are etc.)

2.4 MATHEMATICAL REASONING

2.4.1 DEVELOPING NOTATION AND VOCABULARY (develop new notation and vocabulary to record the actions and results of dealing with real world and other problem situations)

2.4.2 DEVELOPING ALGORITHMS (develop a formal algorithmic procedure for performing a computation or solving a problem of a certain type)

2.4.3 GENERALIZING (extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general terms)

2.4.4 CONJECTURING (make appropriate conjectures and conclusions while investigating patterns, discussing ideas, working with an axiomatic system etc.)

2.4.5 JUSTIFYING AND PROVING (provide evidence for the validity of an action or the truth of a statement by an appeal to mathematical results and properties, or by an appeal to logic)

2.4.6 AXIOMATIZING (explore a formal axiomatic system by relating subsystems, properties, or proposition in the system, consider new axioms and their consequences, examine the consistency of axiom problems etc.)

2.5 COMMUNICATING

2.5.1 USING VOCABULARY AND NOTATION (demonstrate the correct use of specialized mathematical terminology and notation)

2.5.2 RELATING REPRESENTATIONS (work with relationships and related mathematical representations to show the linkages between related mathematical ideas or related mathematical objects)

2.5.3 DESCRIBING/DISCUSSING (discuss a mathematical object, concept, pattern, relationship, algorithm, result or display from a calculator or computer)

2.5.4 CRITIQUING (discuss and critically evaluate a mathematical idea, conjecture, problem, solution method of problem solving, proof etc.)

3. PERSPECTIVES

3.1 ATTITUDES TOWARDS SCIENCE, MATHEMATICS AND TECHNOLOGY - curriculum encourages positive attitudes towards science, mathematics and technology)

3.2 CAREERS INVOLVING SCIENCE, MATHEMATICS AND TECHNOLOGY

3.2.1 PROMOTING careers in science, mathematics and technology

3.2.2 PROMOTING the importance of science, mathematics and technology in non-technical careers

3.3 PARTICIPATION IN SCIENCE AND MATHEMATICS BY UNDER-REPRESENTED GROUPS (curriculum encourages all types of students to study and use science, mathematics and technology. examples of groups that could be targeted: women, racial and ethnic minorities)

3.4 SCIENCE, MATHEMATICS AND TECHNOLOGY TO INCREASE INTEREST (curriculum promotes interest and increasing understanding of topics in science, mathematics and technology by using experiences that are common to students or popular or intriguing information, examples include using sports, news, celebrities, history, literature and interesting data.)

3.5 SCIENTIFIC AND MATHEMATICAL HABITS OF MIND (curriculum encourages ways of scientific and mathematical thinking such as openness, objectivity, tolerance of uncertainty and curiosity)

DETAILED SCIENCE FRAMEWORK CATEGORIES

1. CONTENT

1.1 EARTH SCIENCES

1.1.1 EARTH FEATURES

- 1.1.1.1 Composition (earth's crust, mantle and core, distribution of metals, minerals.
- 1.1.1.2 Landforms (mountains, valleys, continents)
- 1.1.1.3 Bodies of water (oceans, lakes, ponds, bottom of the oceans, rivers)
- 1.1.1.4 Atmosphere (layers of the atmosphere, (ionosphere, stratosphere etc.))
- 1.1.1.5 Rocks, Soil (soil types, soil formation, pH of soils, classes of rocks specific rocks and their uses)
- 1.1.1.6 Ice forms (glaciers, icebergs, Antarctic)

1.1.2 EARTH PROCESSES

- 1.1.2.1 Weather and climate (weather maps, weather forecasts, hurricanes, seasons of the year)
- 1.2.1.2 Physical cycles (rock cycle, water cycle)
- 1.2.1.3 Building and breaking (plate tectonics, earth quakes, volcanoes)
- 1.2.1.4 Earth's history (geologic timetable, formation of fossils, fossil fuels and mineral resources)

1.1.3 EARTH IN THE UNIVERSE

- 1.1.3.1 Earth in the solar system (earth/sun/moon system, night/day, tides, north/south)
- 1.1.3.2 Planets in the solar system (planets' features, order of planets in the solar system)
- 1.1.3.3 Beyond the solar system (galaxies, black holes, quasars, types of stars, constellations of stars)
- 1.1.3.4 Evolution of the universe (origin/history/future of the universe)

1.2 LIFE SCIENCES

1.2.1 DIVERSITY, ORGANIZATION, STRUCTURE OF LIVING THINGS

- 1.2.1.1 Plants, fungi (types of plants and fungi)
- 1.2.1.2 Animals (types of animas)
- 1.2.1.3 Other organisms (types of micro-organisms)
- 1.2.1.4 Organs, tissues (circulatory systems, plant, leaf, systems of movement, eyes, ears.)
- 1.2.1.5 Cells (cell membranes, nucleus, mitochondria, vacuoles)

1.2.2 LIFE PROCESSES AND SYSTEMS ENABLING LIFE FUNCTIONS

- 1.2.2.1 Energy handling (energy capture, storage, transformation-photosynthesis, respiration, biosynthesis (protein, carbohydrate, fat etc.) digestion, excretion)
- 1.2.2.2 Sensing and responding (bio-feedback in systems, homeostasis, sensory systems, responses to stimuli (e.g. nervous system and brain))
- 1.2.2.3 Biochemical processes in cells (regulation of cell functions, translation, protein synthesis, enzymes)

1.2.3 LIFE SPIRALS, GENETIC CONTINUITY DIVERSITY

- 1.2.3.1 Life cycles, (life cycles of plants, insects, etc. growth, development, reproduction, dispersal, ageing, death, cell division, cell differentiation)
- 1.2.3.2 Reproduction (plant/animal/reproduction, sexual/asexual reproduction)

1.2.3.3 Variation and inheritance (Mendelian/non-Mendelian genetics, quantitative inheritance, population genetics)

1.2.3.4 Evolution, speciation, diversity (evidence for evolution, effects of evolution, processes of evolution, (e.g. adaptation, natural selection), nature of a species, domestication, importance of diversity)

1.2.3.5 Biochemistry of genetics (concept of the gene, DNA/RNA, gene expression, genetic engineering)

1.2.4 INTERACTIONS OF LIVING THINGS

1.2.4.1 Biomes and ecosystems (tundra, rain forest, savannah, wetlands, tide pools)

1.2.4.2 Habitats and niches (habitats of endangered species, niches of species)

1.2.4.3 Interdependence of life (food webs/chains, symbiotic relationships, impact of humans)

1.2.4.4 Animal behaviour (migration of birds, mate selection, rearing young, social groupings of animals (e.g. beehives, elephant herds)

1.2.5 HUMAN BIOLOGY AND HEALTH NOTE: Many human biology topics will involve double coding. For example: studying the human digestive system (1.2.1.4 and 1.2.5), human impact on the environment (1.2.5 and 1.6), human reproduction (1.2.5 and 1.2.3.2)

1.2.5.1 Nutrition (vitamins and minerals in diet)

1.2.5.2 Disease (disease types, causes, prevention)

1.3 PHYSICAL SCIENCES

1.3.1 MATTER

1.3.1.1 Classification of matter, (homogeneous and heterogeneous materials, elements)

1.3.1.2 Physical properties (weight, mass, states of matter, malleability of metals, hardness, shape)

1.3.1.3 Chemical properties (periodic table, acidity, reactivity, atomic spectra, organic/inorganic)

1.3.2 STRUCTURE OF MATTER

1.3.2.1 Atoms, ions, molecules (atoms, ions, molecules as the basis for different substances)

1.3.2.2. Macromolecules, crystals, (polymers, shape/function of biological molecules, crystal structure)

1.3.2.3 Sub-atomic particles (electrons, protons, neutrons)

1.3.3 ENERGY AND PHYSICAL PROCESSES

1.3.3.1 Energy types, sources, conversions (potential and kinetic, chemical, nuclear, fossil fuels, hydroelectric power, changing one form of energy to another, energy and work, efficiency)

1.3.3.2 Heat and temperature (temperature scales, heat as a form of energy, heat versus temperature)

1.3.3.3 Wave phenomena (wave properties, types (e.g. IR, UV), wave interactions)

1.3.3.4 Sound and vibration (transmission of sound, acoustics, harmonics)

1.3.3.5 Light (nature of light, optics, luminosity, reflection, refraction)

1.3.3.6 Electricity(static electricity, electrical fields, alternating/direct currents, electrical circuits)

1.3.3.7 Magnetism (magnets and their magnetic fields, magnetic properties,) NOTE Electromagnetism topics should be double coded 1.3.3.6 and 1.3.3.7.

1.3.4 PHYSICAL TRANSFORMATIONS

1.3.4.1 Physical changes (the gas laws, changes in states of matter, mixing)

1.3.4.2 Explanations of physical changes (general explanations for boiling, freezing dissolving etc.)
1.3.4.3 Kinetic theory (kinetic molecular theory)
1.3.4.4 Quantum theory and fundamental particles (quantum nature of light, photoelectric effect)

1.3.5 CHEMICAL TRANSFORMATIONS
1.3.5.1 Chemical changes (definition of a chemical change, types of reactions (e.g. displacement, acid-base, oxidation-reduction, etc.)
1.3.5.2 Explanations of chemical changes (ionic/covalent bonding, electron configurations, electronegativity)
1.3.5.3 Rate of change and equilibria (reagent concentrations, reaction conditions, dynamic equilibrium)
1.3.5.4 Energy and chemical change (types of energy, exothermic, and endothermic reactions)
1.3.5.5 Organic and biochemical changes (types of organic compounds, organic reactions, biochemistry)
1.3.5.6 Nuclear chemistry (fission, fusion, isotopes, half-life, mass/energy conversion)
1.3.5.7 Electrochemistry (electrochemical cells/batteries, electrolysis, oxidation/reduction reactions)

1.3.6 FORCES AND MOTION
1.3.6.1 Types of forces (gravitational force, friction, centripetal force)
1.3.6.2 Time, space and motion (measurement of time, types of motion (linear/rotational) describing motion (constant velocity, acceleration, momentum) reference frames for motion)
1.3.6.3 Dynamics of motion (balanced and unbalanced forces, action/reaction, momentum and collisions)
1.3.6.4 Relativity theory (mass/ energy/velocity relationship, explaining the velocity of light, time frames while travelling at the speed of light)
1.3.6.5 Fluid behaviour (hydraulics, Bernoulli principle, pneumatics)

1.4 SCIENCE, TECHNOLOGY AND MATHEMATICS

1.4.1 NATURE OR CONCEPTIONS OF TECHNOLOGY (Identifying needs and opportunities, generating a design, planning and making, evaluating)

1.4.2 INTERACTIONS OF SCIENCE, MATHEMATICS AND TECHNOLOGY.
1.4.2.1 Influence of mathematics, technology in science (information about contribution of mathematics and technology to the development of scientific thought and the practise of science, e.g. new mathematics and technology make it possible for science to investigate new questions or to analyse data in new ways)
1.4.2.2 Applications of science in mathematics and technology. (information about contributions of science to the development and practise of mathematics and technology, e.g. developments of calculus and classical mechanics, industrial processes, types of simple machines, measuring devices, - thermometer, Geiger counter)

1.4.3 INTERACTIONS OF SCIENCE, TECHNOLOGY AND SOCIETY
1.4.3.1 Influence of Science, technology on society (social, economic, ethical impacts of scientific and technological advances, e.g. influence of scientific ideas on social thought, such as Darwinism, effects of computers on life styles)
1.4.3.2 Influence of society on science, technology (information about influence of society on the directions and progress of

science and technology, e.g. controversies over research in genetic engineering, use of animals in research)

1.5 HISTORY OF SCIENCE AND TECHNOLOGY
(famous scientists, classic experiments, historical developments of scientific ideas, industrial revolution, classic inventions)

1.6 ENVIRONMENTAL and resource issues related to Science

1.6.1 POLLUTION (acid rain, thermal pollution, global warming)
1.6.2 CONSERVATION OF LAND, WATER AND SEA RESOURCES (rain forest, old growth forests, water supplies)
1.6.3 CONSERVATION OF MATERIAL AND ENERGY RESOURCES (fossil fuels versus alternative energy sources, recycling aluminium)

1.6.4 WORLD POPULATION (population statistics, trends, effects of increasing world population, e.g. world hunger, epidemic diseases)
1.6.5 FOOD PRODUCTION, STORAGE (agricultural methods, food supply and demand, distribution methods)
1.6.6. EFFECTS OF NATURAL DISASTERS (environmental damages of hurricanes/typhoons, volcanoes, drought)

1.7 NATURE OF SCIENCE

1.7.1 NATURE OF SCIENTIFIC KNOWLEDGE (scientific methods, knowledge subject to verification, knowledge subject to change)

1.7.2 THE SCIENTIFIC ENTERPRISE (canons of ethics and decision making, professional communication, the scientific community, personnel and processes in large scale research)

1.8 SCIENCE AND OTHER DISCIPLINES

1.8.1 SCIENCE AND OTHER DISCIPLINES (explicit mathematics instruction in the science curriculum

1.8.2 SCIENCE AND OTHER DISCIPLINES (science curriculum incorporated with language arts, social studies or the arts, examples include chemistry of painting, using art or music to represent or illustrate science concepts, studying the role of science in other cultures, writing stories as metaphors that illustrate science concepts)

2. PERFORMANCE EXPECTATIONS

2.1 UNDERSTANDING NOTE: The performance expectation is that students will understand the kinds of information in this category. In some materials, the difference between simple, complex and thematic information may be difficult to distinguish.

2.1.1 SIMPLE INFORMATION (information such as vocabulary, facts, equations, simple concepts, examples include defining, describing, naming, quoting, reciting, etc. specific examples are defining scientific terms, (boiling point, niche), knowing symbols, (abbreviations for units, chemical symbols,), describing simple concepts (materials expand when heated, characteristics of animals)).

2.1.2 COMPLEX INFORMATION Information involving the integration of bits of simple information: examples include differentiating, comparing, contrasting, synthesising, specific examples are understanding how increased external pressure raises the boiling point of liquids, how fire is part of the life cycle of pine trees)

2.1.3 THEMATIC INFORMATION NOTE: This category should not be coded if students are merely expected to name or describe thematic concepts (information about the concepts, with broad applicability that organize and structure knowledge within a discipline and among disciplines: examples include energy, evolution, patterns, change, systems, etc.: a specific example of performance that could indicate understanding of thematic information is using themes to synthesise science knowledge and experiences)

2.2 THEORIZING, ANALYSING AND SOLVING PROBLEMS

2.2.1 ABSTRACTING AND DEDUCTING SCIENTIFIC PRINCIPLES (when presented with precise facts or scientific data, deducing a scientific principal (e.g. when presented with spectra of several stars, deducing the stars' relative temperatures, when presented with data on plant growth, deducing that light is required))

2.2.2 APPLYING SCIENTIFIC PRINCIPLES TO SOLVE QUANTITATIVE PROBLEMS (using physical laws such as f = ma to solve quantitative problems: when given acceleration (a) and mass (m), and calculating force (f); writing and balancing chemical equations, using balanced chemical equations to answer questions about chemical systems, e.g. stoichiometry problems.)

2.2.3 APPLYING SCIENTIFIC PRINCIPLES TO DEVELOP EXPLANATIONS (using gas laws to explain changes in gas temperature, pressure and volume, using ecological principles to predict effect of reducing a populations habitat.)

2.2.4 CONSTRUCTING, INTERPRETING AND APPLYING MODELS (using or creating models that represent systems, objects, events, or ideas, drawing a model of the solar system, making an analogy between human thinking and computer logic.)

2.2.5 MAKING DECISIONS (using scientific skills and knowledge to make decisions regarding personal local or societal issues, examples of issues are water purification, nutrition and resource utilization, air quality and energy production, decision making may include defining the decision to be made, identifying alternative choices, weighing advantages and disadvantages and committing to action on a particular choice.)

2.3 USING TOOLS, ROUTINE PROCEDURES AND SCIENCE PROCESSES

2.3.1 USING APPARATUS EQUIPMENT AND COMPUTERS (calibrating and eye-dropper, reading a meniscus, using pH paper, folding filter paper, preparing a microscope slide, operating a computer, running a computer programme)

2.3.2 CONDUCTING ROUTINE EXPERIMENTAL OPERATIONS (measuring the volume of an irregular solid by displacement of water, conducting a titration, culturing bacteria.)

2.3.3 GATHERING DATA (observing, measuring etc., perceiving characteristics, similarities, differences, and changes through use of the senses, comparing objects or events to standards of length, area, volume, mass, temperature, force, or time.)

2.3.4 ORGANIZING AND REPRESENTING DATA (classifying, constructing graphs, tables and diagrams, organizing materials, events and phenomena into logical groupings, making graphs of data.

2.3.5 INTERPRETING DATA (extrapolating, or interpolating, data from a table or graph, identifying patterns or trends in data.)

2.4 INVESTIGATING THE NATURAL WORLD

2.4.1 IDENTIFYING QUESTIONS TO INVESTIGATE (observing water droplets on outside surface of a drinking glass and forming questions about where the liquid came from, reading about fish dying in local lakes and forming questions about the cause.)

2.4.2 DESIGNING INVESTIGATIONS (developing hypotheses, developing or choosing procedures, selecting materials and equipment.)

2.4.3 CONDUCTING INVESTIGATIONS (executing procedures and recording data) NOTE: Students are often given prescribed procedures and told the expected results and conclusions. Such investigations are sometimes called 'cookbook' experiments, since following the procedures is similar to following a recipe in cooking.

2.4.4 INTERPRETING INVESTIGATIONAL DATA (organizing data, analysing data, using data to address the investigation's hypothesis or questions.)

2.4.5 FORMULATING CONCLUSIONS FROM INVESTIGATIONAL DATA (using data to make conclusions about the questions or hypothesis of the investigation.)

2.5 COMMUNICATING

2.5.1 ACCESSING AND PROCESSING INFORMATION (finding information, using a library, listening to others for information)

2.5.2 SHARING INFORMATION (reporting work to others in written or oral form, communicating in a group to solve a scientific problem)

3. PERSPECTIVES

3.1 ATTITUDES TOWARDS SCIENCE, MATHEMATICS AND TECHNOLOGY

3.1.1 POSITIVE ATTITUDES TOWARDS SCIENCE< MATHEMATICS AND TECHNOLOGY (curriculum encourages positive attitudes towards science, mathematics and technology and/or the study of them.)

3.1.2 SCEPTICAL ATTITUDES TOWARDS THE USE OF SCIENCE AND TECHNOLOGY (curriculum encourages students to evaluate disadvantages of the use of science and technology in society.)

3.2 CAREERS IN SCIENCE, MATHEMATICS AND TECHNOLOGY

3.2.1 PROMOTING CAREERS IN SCIENCE, MATHEMATICS AND TECHNOLOGY (the curriculum materials describe or promote careers in science, mathematics and technology.)

3.2.2 PROMOTING THE IMPORTANCE OF SCIENCE, MATHEMATICS AND TECHNOLOGY IN NON-TECHNICAL CAREERS. (curriculum shows that science, mathematics and technology are important in automobile repairs, accounting, flying aeroplanes etc..)

3.3 PARTICIPATION IN SCIENCE AND MATHEMATICS BY UNDER-REPRESENTED GROUPS (curriculum materials encourages all types of students to study and use science or mathematics, examples that could be targeted - women, racial and ethnic minorities, students in certain regions of a country.)

3.4 SCIENCE, MATHEMATICS AND TECHNOLOGY TO INCREASE INTEREST (curriculum uses experiences that are common to children as a way of increasing understanding topics and/or increasing student interest in topics. popular or intriguing information is used to increase student interest in topics. examples include noting science and mathematics aspects of sports and news, noting celebrities interested in science or mathematics.)

3.5 SAFETY IN SCIENCE PERFORMANCE (curriculum materials describe safe use of materials and equipment, safe procedures.)

3.6 SCIENTIFIC HABITS OF MIND (the curriculum encourages ways of scientific thinking such as scepticism, openness, objectivity, tolerance of uncertainty and curiosity.)

APPENDIX 3

COUNTRY: -SOUTH AFRICA ☐ GUIDELINE ☐ TEXTBOOK ☐ MATHEMATICS ☐ SCIENCE

DOCUMENT ID CODE ☐

UNIT ID NUMBER ☐ PAGE NUMBER ☐ OF ☐ FOR THIS UNIT

Page Number	1	1	1	2	2	2	2/3	3	3	4
Block ID Number	1	2	3	4	5	6	7	7/8	9	10
Block Type	1	1	8	1	8	1	8	2	8	8
Primary Content Codes 1 Secondary Codes	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1	1.1.1
Primary Codes Performance Secondary	2.1.3	2.1.3 2.5.1	2.2.1	2.1.3 2.2.1	2.5.1	2.1.3	2.2.1 2.5.3	2.1.3 2.5.3	2.3.1 2.3.2	2.3.1 2.5.3
Perspective Codes										
Perspective Codes	0	0	3.5	3.5	3.5	0	3.5	0	0	3.5

Block type codes for Curriculum Guides
1.Official Policies
2.Objectives
3.Content Element
4. Pedagogical Suggestions
5. Examples
6. Assessment suggestions

Block type codes for Textbook materials
1. Narrative.
2. Related Narrative
3. Unrelated Narrative
4. Related Graphic
5. Unrelated Graphic
6. Exercise/Question Set
7. Unrelated Questions
8. Activity Block
9. Worked Example
10. Other

FORM COMPLETED BY:	DATE

APPENDIX 3

APPENDIX 4

CURRICULUM FIT ANALYSIS - STANDARD 5 - SCIENCE

NOTE: MCQ = Multiple Choice Question. FRI = Free Response ITem.

TOPIC	CURRICULUM FIT		NO CURRICULUM FIT	
	MCQ	FRI	MCQ	FRI
EARTH FEATURES			A12 B1 C7 D3 E12 F5 G11 H4 O12	R4 W1
OTHER EARTH SCIENCE			B5 R9 H3 I17 J1 K15 Q16	O14 P3 W2 Q11
HUMAN BIOLOGY			A7 B4 C8 D5 E8 F3 G8 H1 I14	O16 P6 Q17 X1
LIFE SCIENCE - OTHER	D6 E10 F1 I11 J7 K18 L3 N6	O17	G9 H2 I10 I19 J2 K11 K12 K16 L2 L5 L6 N2 N4 P4	J9 M11 R3 X2
ENERGY TYPES ETC.	A8 B2 C12 D4	Y1	H5	L4
LIGHT	B6 F2		A10 C9 D1 E11 R1 R2	M14 P2 Q12

PHYSICS - OTHER	D2 I16	N10	B3 E7 G7 J5 K13 K14 K17 L1 L7 N8 O13 P1 Q13 Y2	K1 M12 O10 P5 Q18
CHEMISTRY	H6 J4 M13		A9 C10 F6 G10 J6 J8 M10 N9 O11 O15 Q14 Q15	J3 N7 R5 Z1
ENVIRONMENT	A11		C11 F4 G12 N5	Z2
OTHER CONTENT	P7	K19	I12 I13 I15 N1 N3	I18
MARKS	21		82	
	21	4	82	28

Total = 135

CURRICULUM FIT ANALYSIS - STANDARD 6

TOPIC	CURRICULUM FIT		NO CURRICULUM FIT	
	MCQ	FRI	MCQ	FRI
EARTH FEATURES	D3 F5 O12	R4 W1	A12 B1 C7 E12 G11 H4	
OTHER EARTH SCIENCE	E9 H3 I17 O14 Q16	P3 W2 Q11	B5 J1 K15	
HUMAN BIOLOGY			A7 B4 C8 D5 E8 F3 G8 H1 I14 P6	O16 Q17 X1
LIFE SCIENCE - OTHER	D6 E10 F1 I11 J7 K11 K18 L3 L6 N4 N6	O16 O17 X2	G9 H2 I10 I19 J2 K12 K16 L2 L5 N2 P4	J9 M11 R3
ENERGY TYPES ETC.	A8 B2 C12 D4	Y2	H5	L4
LIGHT	B6 F2		A10 C9 D1 E11 R1 R2	M14 P2 Q12
PHYSICS - OTHER CONTENT	B3 D2 E7 G7 I16 J5 K13 Q13	M1 N10 O10 P5	K14 K17 L1 L17 N8 O13 P1 Y2	K10 Q18

CHEMISTRY	A9 C10 G10 H6 J4 J6 J8 M10 M13 N9 O11 Q14 Q15	J3 N7 R5		P6 Z1
ENVIRONMENT	A11 C11 F4		G12 N5	Z2
OTHER CONTENT	I15 N3 P7	K19	I12 13 N1	I18
NUMBER OF QUESTIONS	53	16	50	16
MARKS	53	16	50	16

TOTAL 135

CURRICULUM FIT ANALYSIS - MATHEMATICS - STANDARD 5

TOPIC	CURRICULUM FIT		NO CURRICULUM FIT	
	MCQ	FRI	MCQ	FRI
A. COMMON FRACTIONS MEANING AND REPRESENTATION	A1 B9 D9 F12 H8 K1 N19	I6		
B. COMMON FRACTIONS OPERATIONS, RELATIONS AND PROPERTIES	C4 E3 G5 I2 K9 L17 M4 N14 N16 P14 Q9	J12 O9 R13		
C. DECIMAL FRACTIONS	B10 D12 F9 I5 J14 L9 N17 O4 Q8 R6 R7	K2 M8 P16		
D. ESTIMATION AND NUMBER SENSE	C6 E4 H9 I7 K6 N11 O2 P12 P13 Q6 R12	U1 V1	J17 L8	
E. CONGRUENCE AND SIMILARITY			A5 C3 E2 J15 K8 P9	
F. OTHER GEOMETRY	B11 D7 K3 N2 M5 N12 Q10		G3 I8 J11 J16 L15 M7 O3 O8 P8 R10	

G. LINEAR EQUATIONS			A2 B12 D10 F11 H10 I1 O7 Q1 R11	T1
H. OTHER ALGEBRA	C5 E5 H12 J18 L13 R9	N13	G6 K4 L11 P10 P15 Q2 Q7	I4 L16 S1
I. DATA REPRESENTATION AND ANALYSIS			A6 B7 C2 E1 G1 H7 L10 M9 O1 P17 Q4 R8	J13 V2
J. PROBABILITY			F8 H11 I9 K7 M3 N18 O5	
K. MEASUREMENT	A3 C1 D11 E6 F10 G2 I3 J10 L12 M1 N15 P11 Q3	K5 O6 S2		U2 V4
L. PROPORTIONALITY			A4 B8 D8 F7 G4 L14 Q5 V3	M6 R14 T2

TOTAL 151

CURRICULUM FIT ANALYSIS - MATHEMATICS - STANDARD 6

TOPIC	CURRICULUM FIT		NO CURRICULUM FIT	
	MCQ	FRI	MCQ	FRI
A. COMMON FRACTIONS MEANING AND REPRESENTATION	A1 B9 D9 F12 H8 K1 N19	I6		
B. COMMON FRACTIONS - OPERATIONS, RELATIONS AND PROPERTIES	C4 E3 G5 I2 K9 L17 M4 N14 N16 P14 Q9	J12 O9 R13		
C. DECIMAL FRACTIONS	B10 D12 F9 I5 J14 L9 N17 O4 Q8 R6 R7	K2 M8 P16		
D. ESTIMATION AND NUMBER SENSE	C6 E4 H9 I7 J17 K6 L8 N11 O2 P12 P13 Q6 R12	U1 V1		
E. CONGRUENCE AND SIMILARITY			A5 C3 E2 J15 K8 P9	

F. OTHER GEOMETRY	B11 D7 G3 K3 N2 M5 M7 N12 O3 P8 Q10 R10	T1	I8 J11 J16 L15 O8	
G. LINEAR EQUATIONS	A2 B12 D10 F11 H10 I1 O7 Q1 R11			
H. OTHER ALGEBRA	C5 E5 G6 H12 J18 K4 L11 L13 P10 P15 Q2 Q7 R9	I4 L16 N13 S1		
I. DATA REPRESENTATION AND ANALYSIS			A6 B7 C2 E1 G1 H7 L10 M9 O1 P17 Q4 R8	J13 V2
j. PROBABILITY			F8 H11 I9 K7 M3 N18 O5	

K. MEASUREMENT	A3 C1 D11 E6 F10 G2 I3 J10 L12 M1 N15 P11 Q3	K5 O6 S2 U2 V4		
L. PROPORTIONALITY	A4 B8 D8 F7 G4 L14 Q5 V3	M6 R14 T2		

TOTAL 151

APPENDIX 5

Selected Provincial meso-analyses of school performance related to the students' home language and the language of instruction.

Table Appendix 5.1 - Province O1 - Mathematics

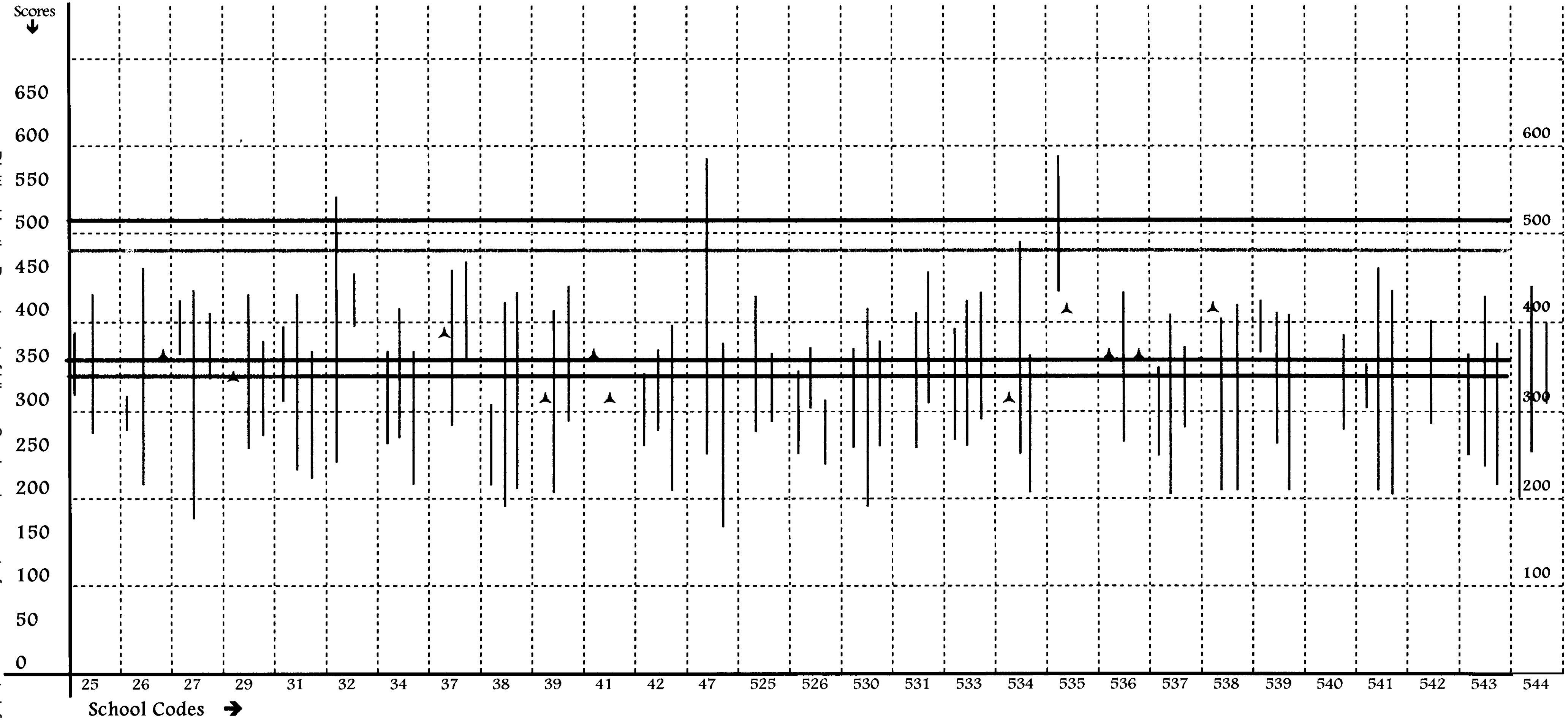
Table Appendix 5.2 - Province O1 - Science

Table Appendix 5.3 - Province O9 - Mathematics and Science

Table Appendix 5.4 - Province O4 - Science

Table Appendix 5.5 - Province O4 - Science

Table Appendix 5.1 Province 01 - Mathematics - Range of marks for each language response

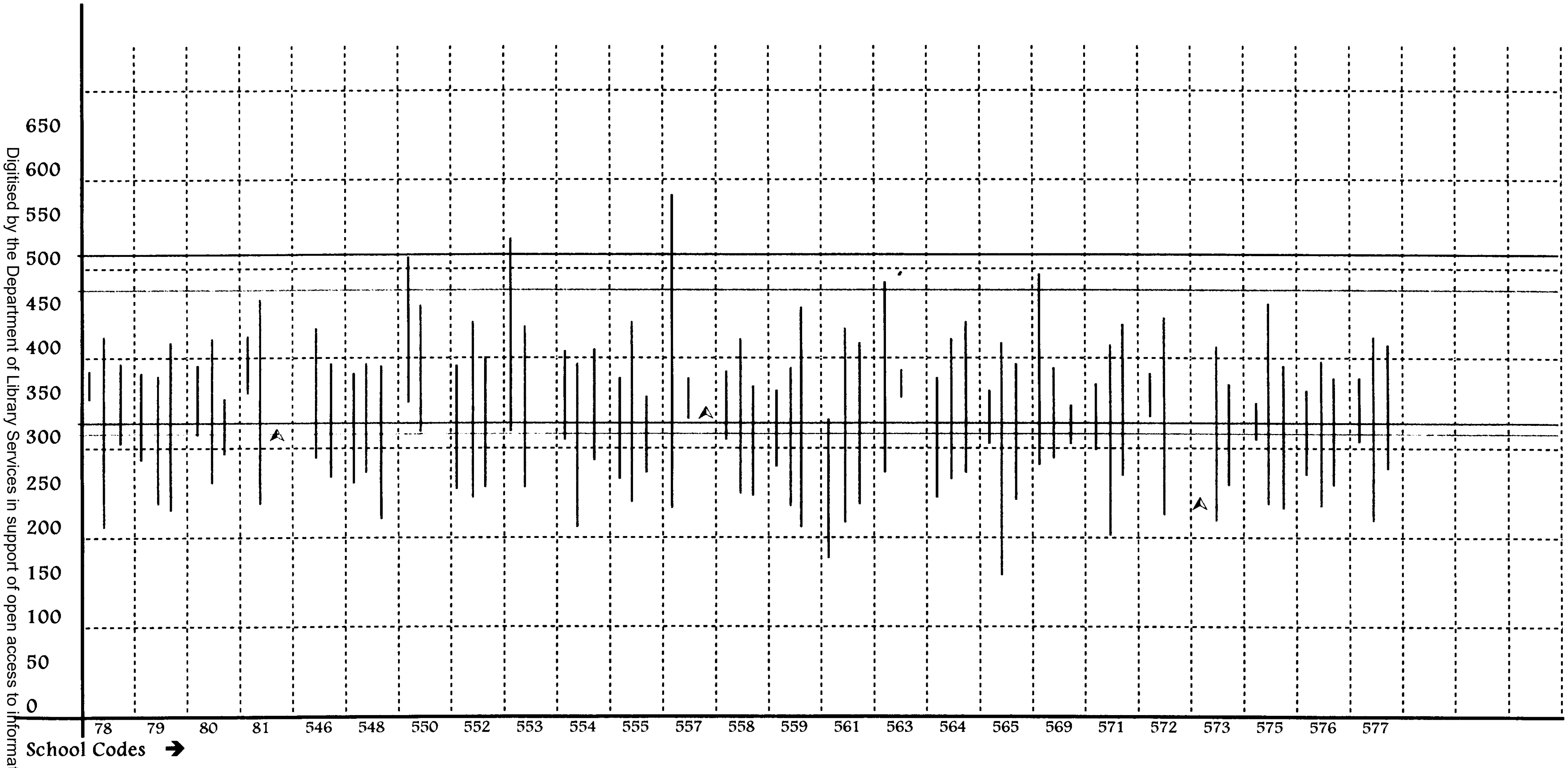


KEY:

Always/Frequently ——— Occasionally ——— Never ——— Single response ⅄ ⅄ ⅄

South African average UG ——— LG ——— International average LG ——— UG ———

Table ***   Province 04 - Science (II) - Range of marks for each language response

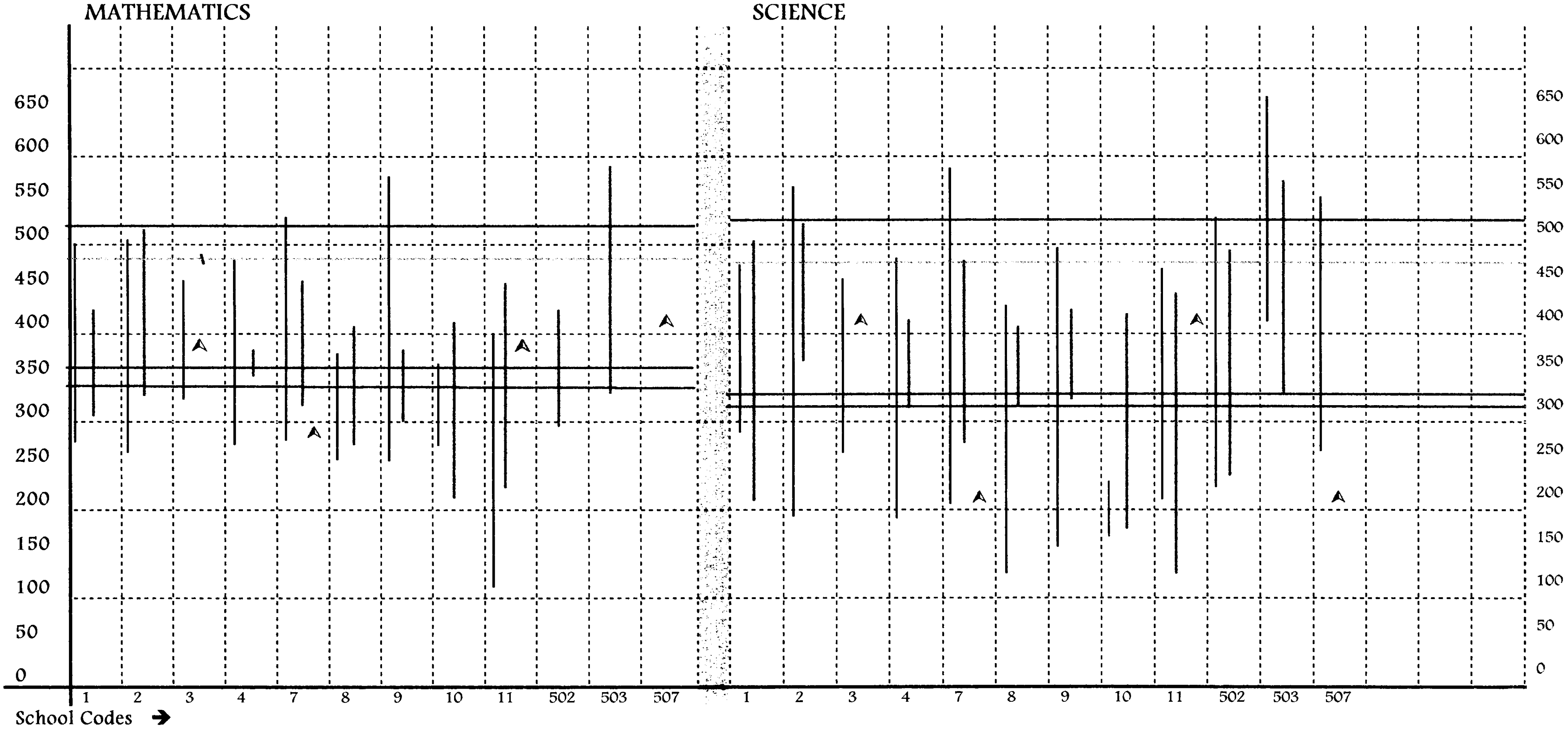


KEY:

Always/Frequently ——— Occasionally ——— Never ——— Single response ⅄ ⅄ ⅄

South African average UG ——— LG ——— International average UG ——— LG ———

Table Appendix 5.3 Province 09 - Mathematics and Science - Range of marks for each language response

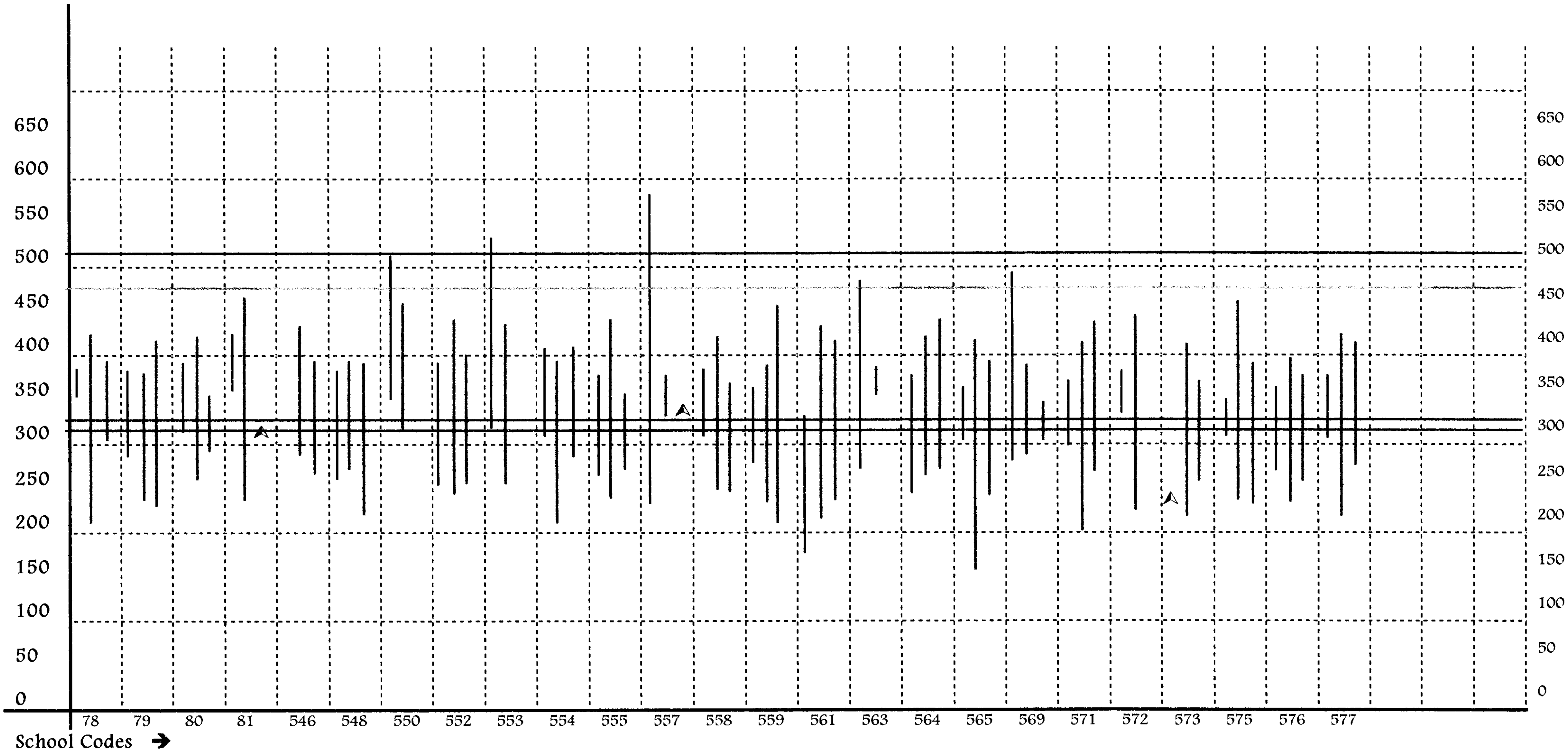


KEY:

Always/Frequently ____ Occasionally ____ Never ____ Single response

South African average UG ____ LG ____ International average UG ____ LG

Table *** Province 04 - Science (II) - Range of marks for each language response

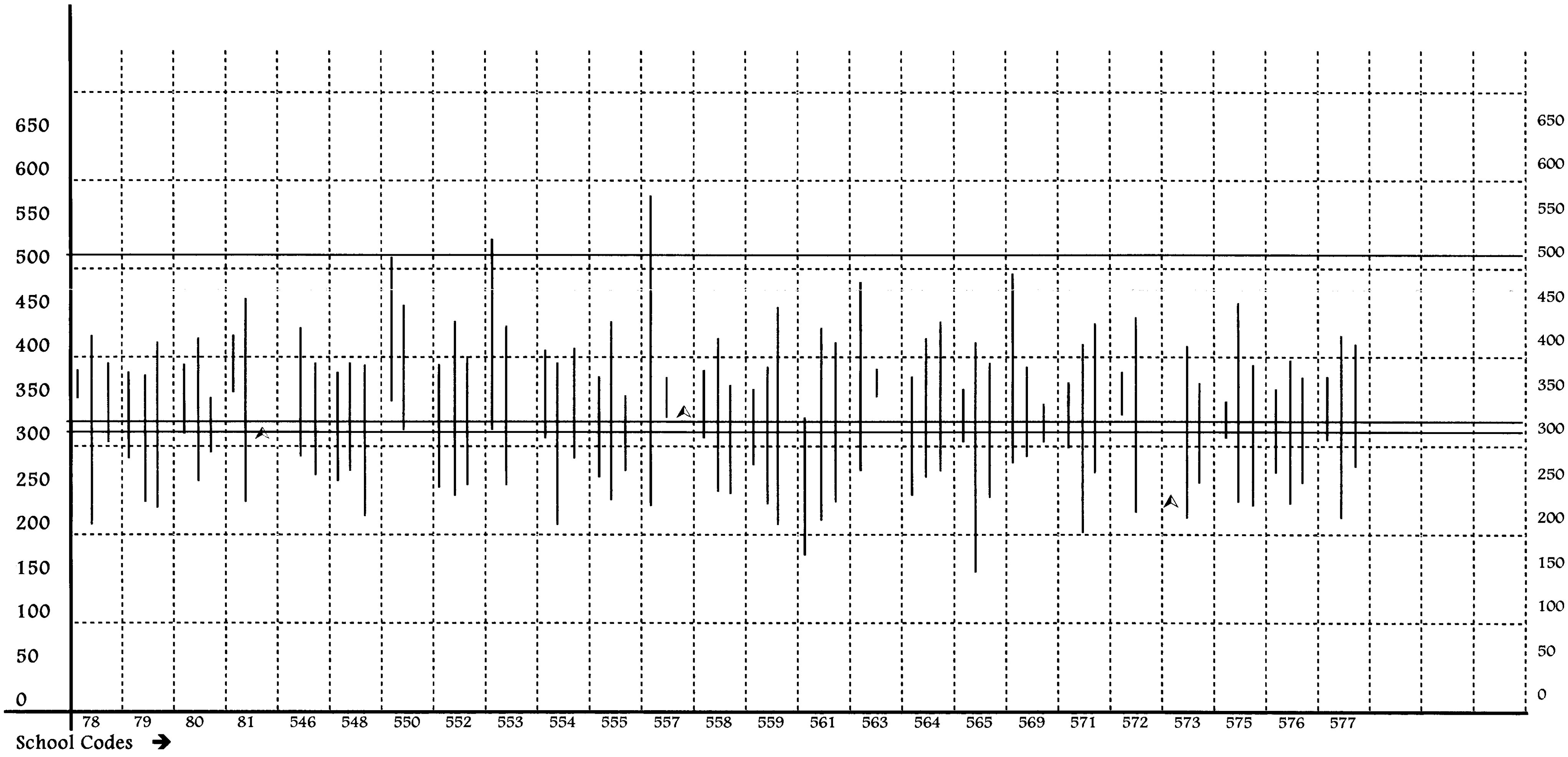


KEY:

Always/Frequently ——— Occasionally ——— Never ——— Single response ⅄ ⅄ ⅄

South African average UG ——— LG ——— International average UG ——— LG ———

APPENDIX 5.5 Province 04 - Science (II) - Range of marks for each language response



KEY:

Always/Frequently ——— Occasionally ——— Never ——— Single response ⅄ ⅄ ⅄

South African average UG ——— LG ——— International average UG ——— LG ———

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