ENGLISH LANGUAGE PROFICIENCY AND CONTEXTUAL FACTORS INFLUENCING MATHEMATICS ACHIEVEMENT OF SECONDARY SCHOOL PUPILS IN SOUTH AFRICA

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PROEFSCHRIFT

ter verkrijging van
de graad van doctor aan de Universiteit Twente,
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door

Sarah Jane Cross

geboren op 12 juni 1967
te Beverley (Engeland)

Promotor

Prof. dr. Tj. Plomp

dedicated to Dave and my family

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LIST OF ACRONYMS

ABET	Adult Basic Education Training
AIDS	Acquired Immune Deficiency Syndrome
ANC	African National Congress
C2005	Curriculum 2005
DoE	Department of Education
FET	Further Education Training
FIMS	First International Mathematics Study
GET	General Education and Training
GETC	General Education Training Certificate
HSRC	Human Sciences Research Council
IAEP	International Association for Education Progress
IEA	International Association for the Evaluation of Educational Achievement
IIEP	Institute for International Education Planning
JET	Joint Education Trust
LV	Latent variable
MLA	Monitoring Learning Achievement
MLN	Multi-level modelling
MV	Manifest variable
NAEP	National Association for Education Progress
NGO	Non-Government Organisation
NQF	National Qualifications Framework
NRC	National Research Co-ordinator
OECD	Organisation for Economic and Cultural development
PLS	Partial Least Squares analysis
RSA	Republic of South Africa
SACD	Southern African Community Development
SACMEQ	Southern African Consortium for Monitoring Educational Quality
SAIRR	South African Institute of Race Relations
SASA	South African Schools Act
SIMS	Second International Mathematics Study
TIMSS	Third International Mathematics and Science Study
TIMSS-R	Third International Mathematics and Science Study-Repeat
UNESCO	United Nations Economic Scientific and Cultural Organisation
UNICEF	United Nations Children's Education Fund

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PREFACE

My first introduction to the IEA and to the TIMSS project was both a nerve-wracking but fascinating experience. I attended a National Research Coordinators meeting in 1995 in Vancouver after my recent appointment to the Human Sciences Research Council as a young researcher. Not knowing that much about the project at that time, it was a humbling but interesting experience as I was introduced into a community of very dedicated, hard-working, and friendly people. Participating in such meetings is also a bit like watching a game of badminton as the debates rage around one and your head whips around following the action. It soon became very evident that the coordination of an international study was a huge and complex task. Soon after I was hit with the realities of running the national study, which was a challenging exercise. I learnt a lot through TIMSS and TIMSS-R and I was certainly privileged to be part of this community for six years and made many friends amongst this group. I owe much thanks to several people (especially Pierre Foy, Marc Joncas, Eugene Gonzalez, Kelvin Gregory, Heiko Sibberns, Knut Schwippert, Dirk Halstedt and Oliver Neuschmidt) who were able to explain a number of complex issues and methods in very easy to understand ways and had seemingly unending patience. In addition to this, the support I received from the then IEA chair Tjeerd Plomp and Study leaders Al Beaton (TIMSS 1995), Mick Martin, Ina Mullis (TIMSS-R) and IEA's Executive Director Hans Wagemaker, Barbara Malak-Minkiewicz and Leendert Dijkhuizen. The funding the South Africa TIMSS-R project received from the World Bank allowed the TIMSS-R project to take place and therefore this research possible.

My dissertation is well travelled, as I was a part-time student studying in the Netherlands but working in South Africa. In between trips to the Netherlands, I travelled with it to more than 15 countries receiving odd looks as I worked in corners of cafés and restaurants, airport lounges, aeroplanes, trains and buses in places such as Slovenia, Morocco and Malaysia. Discussions on the Partial Least Squares Analysis started in Adelaide, Australia with John Keeves who was a valuable and critical friend to me in this project and my gentle introduction to the multilevel analysis took place in Leuven, Belgium with my friend Ann van den Broek. My joint technical discussions with Tjeerd Plomp and Klaas Bos took place in Lubljana, Casablanca, Luxemburg, Boston, Eschede and Edinburgh and therefore the result is a truly global effort.

My homes from home were two households who frequently fed me and often washed my clothes, treated me to variety of delightful Dutch dishes and introduced me to Dutch culture, which included going to work everyday on a bicycle, passing field full of cows and sheep totally different to the highways and traffic jams in Pretoria! I am enormously grateful to my friends (and promotor) Tjeerd and Emmy Plomp for all their hospitality, friendship and assistance and likewise to my friends Klaas Bos and Henny Dijk.

The opportunity to undertake this project would never have occurred if it had not been for my appointment at the Human Sciences Research Council and the support I received from a number of colleagues. I am indebted to Andre Kraak and Mokubung Nkomo for their belief in me to lead the TIMSS-R project and for their ongoing support in embarking for a PhD and undertaking the secondary analysis of the TIMSS-R data.

The conclusion of this research has been largely due to the generosity of my new employers, the University of Pretoria and the vision of my Dean, Jonathan Jansen. He has provided me with the means and an abundance of encouragement to escape long enough from the day-to-day challenges of my office to allow me time to submit to paper the outcomes of my research and have time for reflection. At the same university, my friend and colleague Vanessa Scherman, a member of the original TIMSS-R project team, provided me with lots of encouragement and support at various points over the past three years.
My very sincere thanks go to the Department of Curriculum and its chair, Jan van den Akker, of the Faculty of Educational Science and Technology, for their courage and vision in investing in me, and my PhD research, and awarding me a fellowship. Without this and all their support, none of this research would have been possible. Furthermore, staff and friends at my "other university" at Twente, were superb. In addition to their friendship, they also undertook a range of tasks assisting to make my trips to the Netherlands both enjoyable and productive. Petra Zuithof, Sandra Schele and Paula Krupers all helped in more ways than I can possibly remember in addition to the unenviable task of putting together the final dissertation, and always smiling! Klaas Bos, Martina Meelissen, Marjolein Drent helped to ensure that my stays were unforgettable and helped to keep me fit with their lunchtime walks in the forest. In addition to which Klaas spent much of my first trip to the Netherlands patiently teaching me the skills needed to delve into the data and in subsequent trips engaging in stimulating discussions about the differences between the Dutch and South African data and assisting me in understanding the statistical techniques to be applied. I had many enjoyable talks with Hans Pelgrum who gave me the benefit of his experience

and insights into the data peppered with humour. Susan McKenney and Annette Thijs gave me a lot of moral support and practical advice about dissertations and the university. René Almekinders and Leo de Feiter over the years have provided me with much information related to science and mathematics education and were my first tour guides in the Netherlands for which I am still grateful. In my last trips I was fortunate enough to encounter Charles Matthijssen, who assisted me greatly with the multilevel data analysis applying. In his quiet and very patient way, he helped me to understand the technique involved and to untangle the meaning emerging from the data.

I have been really fortunate to have had a number of mentors who have helped to shape my professional career over the past 12 years and have been involved and taken an interest in my research throughout. I would like to acknowledge both Peter van Eldik and Peter Wedepohl whom I have consulted many times and have given me the benefit of their wisdom and experience. Their continued support, encouragement and friendship have assisted me through some difficult times and I have benefited tremendously from their advice and knowledge. They gave me the courage to undertake many challenges including my PhD and I owe them much.

I consider myself extremely fortunate to have been able to study under the guidance of such an inspirational and generous supervisor, Tjeerd Plomp. He has provided me with exceptional opportunities to develop as person, a student and professional in the field. His continued dedication, support and friendship have made this expedition truly unforgettable, enjoyable and incredibly stimulating. Furthermore, his amazing general knowledge and lessons on Dutch history and art offered me the opportunity to obtain an all around education as an unexpected bonus. Thanks for everything!

Finally, whilst on my expedition, my family and friends stood by observing the continued frenzied activity and the all too familiar statement "Sarah is not here, she is travelling again". Several sacrifices, much tolerance and a lot of patience was demanded from my friends and family and I am very grateful to them for their understanding, and reshuffling of schedules to squeeze me in. Thanks to my parents and brother, David, for their support and even reading the dissertation. To Dave, my pillar of support, my generator of many cups of coffee late at night, who was able to laugh even when I had lost my sense of humour, I am especially grateful.

Pretoria, March 2002

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Several people contributed to the events leading to and culminating in this study. In some cases, some participated actively whilst a number offered their support. However, in one or other way, they contributed to outcome of this research for which I am extremely grateful.

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CHAPTER 1
Introduction

*This study aims to describe and explore the performance of the South African pupils in mathematics and the relationship between mathematics achievement and pupils' proficiency in English, as well as, other background variables. The factors relating to the pupils' performance in mathematics and English language proficiency will be explored in relation to the background information that was also collected from the pupils, teachers and principals of the schools included in the study. This research is linked to a larger project, analysing the performance of the South African pupils in the Third International Mathematics and Science Study-*Repeat *(TIMSS-*R*). TIMSS-*R *was conducted in 1998/1999 in South Africa and internationally under the auspices of the International Association for the Evaluation of Educational Achievement (IEA).*

In this first chapter, an introduction to the research will be given and the central research problem will be described within its context (1.1) followed by the purpose and significance of the study (1.2). Some of the characteristics of this research will be detailed (1.3). Finally the structure for this dissertation will be outlined at the conclusion of this chapter (1.4).

1.1 PROBLEM IN ITS CONTEXT

At the end of the 20th century, "*140 million people in sub-Saharan Africa cannot read or write*" (Asmal, 1999, p. 1). According to Forje (1998, p. 33), *"Africa's continued underdevelopment can be largely attributed to the absence of a science culture in spite of it being the cradle of civilisation"*. Mathematics is the cornerstone of this science knowledge and the foundation for the science subjects; and therefore mathematics literacy is crucial to the development of a "science culture". An inability of the African nations to develop sufficient levels of mathematics, science and technological literacy will condemn them to a continued existence of dependence and poverty. Fundamental to this is the ability to access and utilise information optimally and that can only be achieved through basic literacy, which includes numeracy.

South Africa faces the challenge of providing quality mathematics, science and technology education for its multi-cultural society of approximately 38 million people. However, "*3.5 million adults over the age of 16 have never attended school* and at least *another 2.5 million have stayed a few years in school but through lack of practice can no longer remember how to read and write" (*Asmal, 1999, p. 1). Much of this is directly attributable to the decades of *Apartheid* policies implemented under the white nationalist government of South Africa. These separatist policies forced cultural groups apart through oppression under the guise of separate development. All the country's people were classified into four racial groups, namely African, coloured, Indian and white. The white people (those of European origin) were advantaged at the expense of the non-white group (African[1], coloured and Indian people) who were oppressed in all aspects of life including education. Thus the education system became divided with children of each race group attending schools separated on the basis of these racial groupings. Schools for white children received much more funding than others, had better facilities, were better equipped and had better qualified teachers (see Table 1.1).

Table 1.1
Comparative Education Statistics, 1989

	White	**Indian**	**Coloured**	**African**
Pupil:teacher ratios	17:1	20:1	23:1	38:1
Underqualified teachers	0%	2%	45%	52%
Per capita expenditure including capital	R3 082.00	R2 227.01	R1 359.78	R764.73
Std 10 (grade 12) pass rate	96%	93.6%	72.7%	40.7%

Source: Hofmeyer and Buckland, 1992, p. 22.

Therefore, in addition to the other challenges facing the rest of Africa, South Africa has a set of special circumstances to deal with. These centre on the issue of reconciliation and nation-building and creating a country where the division of two nations, one black and poor and the other white and relatively prosperous is healed.

This complex, but rich diversity in the country is also reflected in the number of official languages of the country (11 dominant languages have been declared). English is spoken as a first language by only 9.1% of the population and yet it is the

[1] Note: African children in homelands and rural areas were educationally more disadvantaged than those in urban areas (Hofmeyer & Buckland, 1992).

language of business and government. It is also one of two languages officially used at schools, although it is not the most widely spoken language at home. As a result the issue around the language policy for teaching and learning has become a sensitive and controversial topic in South Africa and given its history, perhaps even more so than in many other African countries.

1.2 PURPOSES AND SIGNIFICANCE OF THE STUDY

It is against the context described in the previous section that this study aims *to describe and explore the performance of the South African pupils in mathematics and the relationship between mathematical achievement and pupils' proficiency in English, as well as other background variables*. This implies that the study reported in this book will have a descriptive part and an exploratory analytical part.

This research forms part of a broader project, analysing the performance of the South African grade 8 pupils within an international comparative perspective. These pupils participated in the Third International Mathematics and Science Study-Repeat (TIMSS-R). TIMSS-R (see Martin, Mullis, Gonzalez, et al., 2000; Mullis et al., 2000) that was conducted in 1998/1999 in South Africa (see Howie, 2001) and internationally under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). The 'original' IEA Third International Mathematics and Science Study (TIMSS) with data collection in 1995 was the first international study of mathematics (and science) achievement that South Africa participated in. The South African TIMSS results are reported in Howie and Hughes (1998).

Both TIMSS and TIMSS-R are international comparative survey studies in which the performance of pupils in mathematics and science, as well as background information from pupils, teachers and schools were collected from a representative sample of pupils in each of the participating countries (see chapter 4). The descriptive part of the research reported here is based on the South African and international results and outcomes of TIMSS-R.
The second part of this research is analytical in character as it will explore to what extent the performance of South African pupils (in grade 8) in mathematics and English language proficiency is related to factors derived from the background information that was collected from the pupils, teachers and principals of the schools included in the study. This part of the study will make use of path analysis

and multi-level analysis techniques, and in doing so it builds on the work done by a number of researchers from other countries (Afrassa, 1998; Mohandas, 1999, amongst others) and most recently upon the study conducted by Bos (2002) on pupil achievement in mathematics in the Netherlands.

This study is significant for the South African context for several reasons.
Firstly, it analyses the data of the TIMSS-R study in search for explanations of the performance of South African pupils in mathematics. In doing so it is the first major research project in South Africa investigating the influence of English language on pupils' performance in mathematics using a national sample within the framework of an international study. The findings should help to inform the current debate and policies on language of teaching and learning in South African schools.
Another area of significance is that this study investigates factors on student-, class- and school- level that impact on pupil achievement in mathematics. The findings will provide policy-makers, school principals and mathematics educators with information about school and classroom factors related to pupils' achievement.

Moreover, this study will contribute to education research in South Africa in general, as there are no major studies of this nature in South Africa. The combination of a nationally representative achievement survey within an international comparative context, followed by path analytical and multi-level approaches represents an important step in education research in the country with regard to capacity building for these type of studies, which is relevant for similar national, regional and international studies.

Finally, this research has implications for other developing countries in the identification of the factors influencing achievement within the developing world scenario.

1.3 SOME CHARACTERISTICS OF THE STUDY

As indicated, the research reported builds upon the TIMSS-R, an international comparative survey study in which data on mathematics (and science) achievement and background information from pupils, teachers and principals were collected from national representative samples. The implication of this is that the South African sample and the data that were collected had to meet very rigorous international standards. As the South African study met all the sampling criteria, its results in the form of indicators for achievement and background variables can be generalised to the country as a whole, while the study also provides data whereby comparisons can be made realistically with other countries.

The character of TIMSS-R as a survey study, in which data were collected through achievement tests and questionnaires at one point in time, gives the study some special features that can be seen as 'the price' that has to be paid to obtain national representative indicators and that have to be taken into account when interpreting the data and their analyses.

The exploratory analytical part of the research reported here was limited by the data that were collected in the TIMSS-R study. During the conceptualisation of the study it became apparent that, although it would be ideal to explore additional factors influencing mathematics achievement, this could not be done, as it had not been included in the TIMSS-R data collection.

Another point is inherent to the character of TIMSS-R as a cross-sectional international comparative study. The data were collected to the end of the academic year in 1998 in southern hemisphere countries, such as South Africa, and the end of the 1998-99 school year in northern hemisphere countries, which determines the reference point for the results, although there are no indications that since 1998 drastic changes have occurred in South Africa's mathematics and science education. A number of other points has to be taken into account when interpreting the results of TIMSS-R and the research reported here, such as:

- The contextual information was gathered by questionnaires resulting in some self-reported data. Therefore for many internationally comparative indicators the trends are more valuable than the actual specific information from individual respondents for example.
- The tests were designed for international comparisons and, although trying to take into account the curricula of all countries, they do not represent a country's curriculum completely, but are seen as being equally fair/unfair to the countries in the study.
- Related to the previous point, the achievement test does not provide an all-encompassing evaluation of an individual grade 8 pupils' ability in mathematics. It is rather intended to provide information about the performance of a country's system in general, on what is considered for grade 8 pupils a core part of the domain of school mathematics (and sciences).

Some of these points have been addressed in TIMSS-R. For example, given the concerns about the fairness of the achievement test for a country's curriculum, an analysis of the test questions was made (Mullis et al, 2000; see chapter 5 for details). This so-called test-curriculum match analysis attempts to compare the performance of pupils on the questions that were covered by their country's curriculum as compared with the remaining test questions as well as the international test as a whole. The conclusion of Mullis et al. (2000) was that the TIMSS-R achievement test appears to be quite robust: across all the countries there was very little difference between how well pupils performed (on average) on questions representing their own country's curriculum as compared to their performance on all the test questions.

1.4 STRUCTURE OF THE THESIS

Chapter 2 provides an overview of the South African context, the schooling system during the 1990's and the educational reform after 1994 and describes the status of mathematics education in secondary schools in South Africa as well as the language-in education policy and practice in South Africa.

A review of the literature, related to pupils' achievement in mathematics is given in Chapter 3. This includes research done internationally and examines the international comparative studies conducted by the IEA and reviews the major findings. Thereafter, a review is made of the studies conducted thus far in South Africa regarding mathematics achievement in secondary school. Thereafter, the literature on English language proficiency and its relationship to achievement in mathematics is examined as well as the related issues of multi-lingualism and bilingualism in mathematics classrooms in secondary schools. Finally, factors related to mathematics achievement are discussed on student, classroom and school levels with the most important and commonly found factors being described.

A description of the TIMSS-R project is given in Chapter 4. This chapter outlines the background to the project including some of the technical aspects and the methodology that was used in South Africa. The design, conceptual framework and research questions, sample, instrument development, test design, questionnaire development, data collection and data processing are all summarised in this chapter.

Chapter 5 focuses on the design for this particular study. The conceptual framework, the problem statement and the research questions underpinning this research are presented. The analysis plans are described, followed by a discussion on some design issues related to the study.

The data analysis methods are presented in Chapter 6. Partial Least Square (PLS) analysis is described to provide some background for the results given in Chapter 8. The hypothesised models on student-, classroom- and school-level are given and the factors inside the models are described. The methods and procedures used when applying PLS are also discussed. An overview of the multi-level analysis is also described in the chapter and the methods and procedures are summarised.

The results of the first phase of the analysis are described in Chapter 7. Here data on a descriptive level are given: with some data on mathematics achievement being given, a number of other indicators and data such as English language proficiency, and student, teacher and school background characteristics are summarised.

Chapter 8 describes the results from the path analysis using Partial Least Squares analysis. Results are given on the student-, classroom- and school-levels and each model is presented with the factors that have direct and indirect effects on pupils' achievement in mathematics. At the end of the chapter an analysis is made of the factors that have a direct effect on achievement in relation to the conceptual framework for the study.

In Chapter 9 the results of the analysis using Multi-level modelling are given. The preparation for the process is briefly described and the results from the analysis of the two-level model are interpreted and the final model for the study is presented.

In Chapter 10, the research approach and the main findings are summarised. Issues arising from the results are discussed, with regard to achievement, language of learning, teachers and teaching, and the curriculum. Finally the conclusions and recommendations for research in developing countries and for education policy and practice in South Africa are given.

CHAPTER 2
The schooling system in South Africa

South Africa is a country with natural wealth and many cultures. It is also notorious for the Apartheid policies that have left a lasting impression on the education system in the country. Evidence of this lies in the still appalling conditions in many schools across the country, and these conditions exist primarily in the previously so-called African, coloured and Indian schools. South Africa, since the first democratic elections in 1994, has embarked on a substantial reform effort in many areas including education. The system-wide reform efforts have targeted several aspects of education including teacher training, facilities and resources. The most ambitious of these is the introduction of Curriculum 2005 and the move towards outcomes-based education. This was met with some opposition and implementation difficulties. The revision of Curriculum 2005 occurred during 2001 and was supposed to be implemented as from 2002. The language in education policies are currently under development and attempt to address the issue of how to implement 11 official languages of instruction in more than 28 000 schools

In this chapter, the background to the South African context is provided. Firstly, a general overview of the country is given in 2.1. In 2.2, a description of schooling in South Africa is presented where the reform of the education system is briefly discussed. Thereafter a summary of Curriculum 2005 is given in 2.3, followed by an overview of mathematics education in South Africa (in 2.4), whilst the current development of languages-in-education policies and practices in South African schools is discussed in 2.5.

2.1 SOUTH AFRICAN CONTEXT

South Africa with an area of a 1 220 088 km^{2}, is located at the southern part of the African continent and is bordered by Namibia, Botswana, Zimbabwe, Lesotho, Swaziland and Mozambique. Prior to 1994, the country was enveloped in a political policy of Apartheid resulting in the segregation of the country's people on the basis of racial groups. This policy permeated throughout all aspects of life effectively silencing the rights of the majority of South African citizens. Following the first democratic elections in 1994, the country's borders were redefined into nine provinces, the Western Cape, Eastern Cape, Northern Cape, KwaZulu Natal, Free State, Gauteng, North West, Mpumalanga and Limpopo[1]. These provinces incorporated both the former official four provinces of the Republic of South Africa, and the former homelands, the self-governing territories established as part of the Apartheid legislation.

The heaviest population densities occur in the KwaZulu (20.3% of the national population) and the Gauteng (18.9%) provinces. The population is characterised by considerable variance in the distribution of wealth, living conditions and opportunities for advancement. The United Nations Development Programme [UNDP] (1994) ranked South Africa third in sub-Saharan Africa in terms of the human development index. The country was placed after Seychelles and Mauritius. However, there are still significant disparities between the development of the 'advantaged and disadvantaged' population groups in the country. Overall, South Africa was ranked 90th out of 175 countries by the UNDP. The estimated annual population growth in South Africa according to the 1996 census data is 1.9%. Other estimations are higher, ranging from 2.06% – 2.59%.

Compared to the rest of Africa, South Africa is regarded as having a strong economy. It is rated by the World Bank as an upper-middle country, with a gross domestic product of $3 210 (UNESCO, 1999, p. iii, 6-17). However, a report on poverty published in May 1998 found that just under half of the population lived below the poverty line, a large proportion being in the rural areas. Skills shortage and unemployment are serious problems in South Africa. The South African Institute for Race Relations [SAIRR] (1997) estimated the unemployment rate as 24% in 1996. This rate is increasing by two percentage points per year and could reach 43% by 2006. However, the serious pandemic of HIV/Aids affecting about 20% of the population could affect these projections.

2.2 REFORM OF THE SOUTH AFRICAN EDUCATION SYSTEM

South Africa's education system is still deep in the throes of reform. However, it is marked by crises at each level of the system. Poor communities, in particular, those of rural Africans bear the brunt of the past inequalities and many learning sites are

[1] Previously known as the Northern Province and renamed in February 2002.

under threat of violence. South Africa's political history is well known and its impact on the education system (and the youth that have passed through this system) is especially devastating (see: De Villiers, 1997). The illiteracy rate of 55% amongst South Africa's disadvantaged communities illustrates this clearly (Gouws, 1997).

Initially, the Ministry focused on dismantling apartheid structures and establishing a more equitable basis for the financing of education. This was encapsulated in the vision of the government:
"… of a South Africa in which all people have equal access to lifelong education and training opportunities which will contribute towards improving the quality of life and build a peaceful, prosperous and democratic society." (Department of Education [DoE], 1996)
Spending was reoriented towards one budget, '*allocated on the basis of racial equity, and towards redress*'. Primary school nutrition and school renovation projects were key programmes of the Reconstruction and Development Programme (1995-1997). Since 1994, a vast number of policies flooded the education system. Those that were intended to impact on secondary education included:

1. *White Paper, Education and Training in a Democratic South Africa: First Steps to Develop a New System* (February, 1995), which was seen as the fundamental framework of the education system. This was based on the 1994 education policy framework of the African National Congress and has served as the main reference for subsequent policy and legislative development.
2. *The National Education Policy Act (NEPA)* (Republic of South Africa [RSA], 1996), which amongst others provides for the determination of national policies in general and further education and training for among others, curriculum, assessment, language policy and quality assurance.
3. *The South African Schools Act (SASA) (1996*) was designed to promote access, quality and democratic governance in the schooling system. It emphasises that '*all learners have the right of access to quality education without discrimination, and makes schooling compulsory for children aged 7 to 14'.* The Act provides for democratic school governance through school governing bodies and for two types of schools, namely, independent schools and public schools. The priorities of the school funding norms are redress and poverty. These are reflected in the funding allocations to the public schooling system.
4. The *Further Education and Training Act (1998), Education White Paper 4 on Further Education and Training (1998)* and the *National Strategy for Further Education and Training (1999-2001)*, provide the basis for developing a nationally co-ordinated further education and training system, comprising the senior secondary component of schooling and technical colleges. Amongst others they provide for programmes-based funding and a national curriculum for learning and teaching.

5. The *Employment of Educators Act* (RSA, 1998), was instituted to regulate the professional, moral and ethical responsibilities and competencies of teachers.
6. The *South African Qualifications Authority (SAQA) Act* (RSA, 1995) provides for the creation of the National Qualifications Framework (NQF). The NQF 'scaffolds' the national learning system that integrates education and training at all levels.
7. *Curriculum 2005 (C2005),* (DoE,1997a) focused on general education. The aim was to '*move away from a racist, apartheid, rote learning model of learning and teaching to a liberating, nation-building and learner centred outcomes-based one*' (DoE, 2001, p. 5). It aimed to allow greater mobility between different levels of education and institutional sites, and to integrate knowledge and skills through "learning pathways". C2005's assessment, qualifications, competency, and skills-based framework sought to encourage the development of curriculum models attuned to the NQF in theory and practice. More about C2005 is discussed in section 2.3.

South Africa's present education system is an amalgamation of 19 different education departments that merged in 1995 as a result of the change in government policies. Under-resourced and often mismanaged in the past, many of these departments provided insufficient and ineffective education to millions of young people, especially those from the African community. Presently, nine provincial departments of education are directly responsible for the management and administration of education in schools within their provinces.

The South African education system accommodates in the order of more than 12.3 million pupils (50.5% female), 300 000 university students (54.6% female), and 190 000 technikon students (45.5% female). The system encompasses 29 386 primary and secondary schools, 375 000 educators, 5 000 inspectors and subject advisers, and 68 000 officials, managers and support personnel (DoE, 2001a, p. 157-161). There are 156 technical colleges accommodating 125 000 students in the Further Education and Training (FET) sector. Equity and access are at the top of the government's priority list and access has improved to the extent that primary education is almost universal. However, only 86% of South African pupils are enrolled at secondary school, although the net enrolment of 52% as of 1995 (World Bank, 1998) is still of concern to the government (DoE, 2001a, p. 5). In total, South Africa spends about six percent of its GDP on education[2] (about $6 billion in 2000)

[2] In 1998/1999 23% of the total national budget was allocated to education and amounted to R46.8bn.

(DoE, 2001a, p. 15). South Africa spends 8% of its Gross National Product on education annually (World Bank, 1999), which is high compared to other developing countries. Spending on education has been consistently high in this country with the bulk of the education budget being spent on teachers' salaries.

Education in South Africa is compulsory and free for grades 1 to 9, and non-compulsory for grades 10 to 12. Pupils are only expected to pay fees for grades 10 to 12, but educational user fees are widespread across all the grades. Formal education has been re-categorised into three levels. The General Education and Training (GET) band incorporates a reception year and pupils up to Grade 9, as well as an equivalent adult basic education qualification. The Further Education and Training (FET) band comprises Grades 10-12 in school education, out-of-school youth and adult learners. Technical, youth and community colleges, as well as a range of other industry-based and non-formal providers, also fall into the FET band. The Higher Education (HE) band incorporates a range of national diplomas and certificates up to and including postdoctoral degrees. These levels are integrated within a National Qualifications Framework (NQF) (see Figure 1) provided for by the South African Qualification Authority Act (RSA, 1995).

National Qualifications Framework Structure

NQF Level	*Bands*	*Types of Qualifications and Certificates*	
8	Higher Education and Training Band	Doctorates, further research degrees	
7		Higher Degrees, professional qualifications	
6		First Degrees, Higher Diplomas	
5		Diplomas, Occupational Certificates	
4	Further Education and Training Band	School/College/Training Certificates/ Mix of units from all (NGOs)	
3		School/College/Training Certificates/ Mix of units from all (NGOs)	
2		School/College/Training Certificates/ Mix of units from all (NGOs)	
1	General Education and Training Ban	Senior Phase	ABET Level 4 *
		Intermediate Phase	ABET Level 3
		Foundational Phase	ABET Level 2
		Pre-school/ECD	ABET Level 1

Note: * ABET is Adult Basic Education and Training.

Figure 2.1
National Qualifications Framework

South Africa has both government (public) and private (independent) schools within its education system. Funding for public (government) schools originates from the provincial administration derived from a budget that is determined by the national department of education. Only a small proportion of all pupils (3%) in South Africa are enrolled at private schools. The average teacher/pupil ratio at 25:1 in these schools is more favourable than that in government funded schools (which is on average 40:1); and the ratio can even be as low as 14:1.

A considerable number of schools in South Africa suffer serious shortcomings, ranging from poor access to water, telephones and electricity, to the poor condition of many school buildings. In an HSRC survey of school needs (Human Sciences, Research Council [HSRC], 1997), 12% of schools had no sanitation facilities, 24% had no water within walking distance, and 59% had no telephones. Only 49% of schools had adequate provision of textbooks. Furthermore, few schools have well-equipped libraries and many communities are without community libraries leaving the majority of people with little access to reading materials as even the most basic of books are unaffordable for most people and most homes have few books and other reading materials. In general, the supply of ordinary textbooks is greatly restricted by financial constraints. Reading in African languages also appears to be on the decline resulting in many attributing the poor matriculation examination results to pupils' poor reading skills.

Influenced by these and a number of other factors, the ethos at South African schools has deteriorated over the years, making it at times not conducive to academic activity. Teacher rationalisation, one of the most dominant educational debates over the past three years, has contributed to this decline. This process involved voluntary severance packages and redeployment of teachers to other areas. The insecure environment in which teachers have had to operate (large classes, the threat of unemployment) has resulted in low teacher morale and disillusionment. Another worsening problem in South African schools is the prevalence of violence. The department of education launched a 'Culture of Teaching and Learning' campaign to eliminate drugs, rape and sexual harassment, vandalism, weapons and all forms of violence, in an attempt to restore a work ethic in schools.

Most teachers in general have a 3- or 4-year teaching diploma from a teacher training college, although teacher training is also offered at postgraduate level at universities and technikons. Due to an excess of teacher training colleges, several of them were closed or amalgamated during the late 1990s and by 2001 the last of the colleges had amalgamated with universities and technikons. In addition to the financial reasons for this closure there were also reasons linked to quality, especially regarding mathematics and science. Most South African mathematics and science teachers are not qualified to teach these subjects. Although 85% of mathematics teachers are professionally qualified, only 50% had specialised in mathematics; and of the 84% of professionally qualified science teachers, only 42% had qualified in science. Furthermore, many teachers lack the motivation and passion as teaching was not their first choice of career (Howie, 1999).

2.3 OUTCOMES BASED EDUCATION AND CURRICULUM 2005

Curriculum 2005 provides the vision of what learning and teaching should be according to society's goals. It incorporates what is to be learned, processes of learning, teaching and assessment, relationships, power and authority in the system and in schools. During the apartheid period, the curriculum was very prescriptive, content heavy, detailed and authoritarian with little space for teacher initiative (Jansen, 1999). Teaching was primarily chalk and talk and resorting to a strong dependency on the textbooks whilst pupils depended heavily on rote learning. In an attempt to depart from this status quo, the government introduced Curriculum 2005 (C2005), which was a huge and ambitious enterprise to radically reform education. The underlying principle of this curriculum reform was that of outcomes-based education.

A number of issues had to be dealt with prior to C2005. These included creating national and provincial education departments to provide leadership and administration; designing the National Qualification Framework (NQF) and related administrative structures; establishing policies and frameworks for school governance and financing; improving equity and capacity in the distribution of teachers, resources and facilities; building the professionalism of school managers; and reframe teacher education.

This new focus on pupil-involvement required schools and teachers to take major roles in curriculum design: according to pupils' experiences and needs. They were also expected to take major responsibilities for the assessment of pupils' achievements as both a guide to teaching and learning and also for the purpose of reporting and accountability for the system. School managers were expected to provide professional leadership in curriculum. Provincial departments, especially at the district level were expected to provide professional support and leadership in curriculum, management and quality assurance. All these stakeholders as a result required professional development and training. Finally, systems of quality assurance and accountability had to be established, for answerability purposes to communities and the nation.

Curriculum 2005 was developed through an extensive process of participation and consultation and was released in 1997 (DoE, 1997a). It was considered by its developers as being one of the most progressive of such policies in the world. It was driven by principles of outcomes-based education, pupil-centred education and the critical outcomes of the NQF. It specified specific outcomes and standards of achievement across eight learning areas. These outcomes reflected a major change in what was supposed to be learnt in schools. It emphasised competencies rather than particular knowledge. The outcomes outlined learning areas more broadly than in traditional 'subjects' and in so doing created links from subject knowledge to social, economic and personal dimensions of learning. The concept of pupil-centred education meant that pupils were to be involved as participants in curriculum and learning, in a way that responded to their learning styles and cultures, and built on their life experiences and needs.

However, C2005 was attacked from many quarters (Jansen, 1997; Tema, 1997; amongst others). The new curriculum came under fire for several reasons, primarily due to the anticipated difficulty of implementing it in a system with so many under-prepared and under-qualified teachers.

Implementation began in 1998 in Grade 1. This was followed by Grade 2 in 1999, Grades 3 and 7 in 2000, Grades 4 and 8 in 2001, and was supposed to be followed by Grades 5 and 9 in 2002. Simultaneously programmes in teacher education and classroom support were implemented, involving national and provincial education departments, NGOs, television and newspapers, higher education institutions and private publishers. There were widespread concerns regarding the implementation of C2005. The basic documents themselves problematic also led to a variety of interpretations by trainers, education department officers, NGOs, and writers of learning materials. This was further exacerbated by the fact that most of the teachers and trainers own experience and habits were very different to those outlined in C2005. Additionally, very few teachers and trainers had first-hand knowledge of the types of curriculum and teaching envisaged and very few schools had the capacity to manage the changes. In cases where schools and teachers embraced pupil-centred education, the original vision of C2005 was lost in the implementation. Due to the attention drawn to integrating learning areas, the progression of concept development from grade to grade was also often lost.

As the critics had warned the implementation became extremely problematic resulting in the establishment of the Curriculum Review Committee (named the Chisholm Committee after its chair) by the then newly appointed Minister of Education. The conclusion after a 3-month study in 2000 was that: the complexity of the structure and design of the curriculum had compromised the implementation of C2005. Furthermore, poor departmental support to teachers, weak support of teacher training, tight deadlines, the lack of enough learning support materials and the general lack of resources had negatively affected the implementation of C2005 (Chisholm, 2000, p. 27). The Committee recommended that C2005 be revised.

A Ministerial Review Committee was established by the Minister of Education in response to the findings of the Chisholm Committee and its task was to refine the C2005 policy documents. A Ministerial project Committee was established to lead, plan and implement the process. A Task team of eight coordinators of the learning area working groups as well as four additional co-ordinators were appointed.

The main findings that had to be addressed were in brief (DoE, 2001a, p. 21-22):

- There was wide support for the curriculum changes envisaged (especially its underlying principles), but levels of understanding of the policy and its implications were highly varied.
- There were basic flaws in the structure and design of the policy. In particular, the language was often complex and confusing (including the use of unnecessary jargon). Notions of sequence, concept development, content and progression were poorly developed, and the scope of the outcomes and learning areas resulted in crowding of the curriculum overall.
- There was a lack of alignment between curriculum and assessment policies, with insufficient clarity in both areas.
- Training programmes, in concept, duration and quality, were often inadequate, especially early in the implementation process.
- Learning support materials were variable in quality, and often unavailable.
- Follow-up support for teachers and schools was insufficient.
- Timeframes for implementation were unmanageable and unrealistic – the policy was released before the system was ready, with timeframes that were too rushed.

A revised set of National Curriculum Statements was published at the end of July 2001 (DoE, 2001a), for public discussion. The revisions were to simplify the structure, redefine the outcomes, and provide more guidance on progression and content. As part of the National Statements, the assessment standards were prepared for each grade level, and in each outcome. The processes and structures to support implementation were also redeveloped. It was also decided that the fundamental principles underpinning the revised national curriculum should be:

- Outcomes-based education
- Social and environmental justice, human rights and inclusivity
- A high level of skills and knowledge for all
- Balance of progression and integration
- Clarity and accessibility

At the core of the revised national curriculum statement are eight learning area statements in the GET band (DoE, 2001a, p. 13) that state that the kind of pupil envisaged will for example: *"Be equipped with the linguistic skills and the aesthetic and cultural awareness to function effectively and sensitively in a multi-lingual and multi-cultural society"*.

Also included are the critical and development outcomes derived from the Constitution that describe the kind of citizen that the education and training system should aim to produce. The critical outcomes are intended to enable pupils to for instance: *"Communicate effectively using visual, mathematical and language skills."* (DoE, 2001a). Developmental outcomes are also specified. For instance these are supposed to enable pupils to: *"Participate as responsible citizens in the life of local, national and global communities"* (DoE, 2001a).

As mentioned earlier, C2005 moved away from the discipline-based subjects, as they existed in the old curriculum, towards learning areas. The eight learning areas are: Languages, Mathematics, Natural Sciences, Technology, Social Sciences, Arts and Culture, Life orientation, Economic and Management Sciences.

The first phase of C2005 is said to have provided the basis for a 'transformative curriculum' whilst this second phase (the revision) has added substance to C2005. At this stage (February, 2002), the process of developing eight learning area statements (i.e.: learning outcomes and assessment standards) and the Qualifications document has been completed. Feedback from the public has been received and already the provinces have indicated that the statements can be implemented more easily and are clearer to understand. The main differences between the original C2005 documents and the revised versions are that there are fewer curriculum design features, fewer outcomes, that environmental education has been integrated into the curriculum as has human rights and inclusivity issues, that there are assessment exemplars, that there is clear guidance to teachers on what to teach at every grade and phase, that there are implementation guidelines and that there is a qualification document for GETC.

Finally, it was proposed that the revised National Curriculum Statement would become policy at the end of 2001. However this was still not the case in March 2002. In 2002, piloting will take place as will preparation for teacher orientation and the development of policy for learning support materials. In 2004, implementation will occur for Grades R[*] to 3 and in 2005, grades 4-6. Grades 7,8, 9 will be implemented in 2006, 2007 and 2008 respectively. The timelines imply that the first pupils to come out of the streamlined curriculum will be in 2009. However, there are also suggestions that if schools are able to implement the new curriculum earlier they may be allowed to do so.

2.4 MATHEMATICS EDUCATION IN SOUTH AFRICA

The ANC policy framework document (African National Congress [ANC], 1994) aptly described the situation in mathematics (and science) education at the time of the new democratic dispensation in African schools in South Africa as being characterised by a cycle of mediocrity. The same document clearly states that the infrastructure for the teaching of science and mathematics is poor, especially at senior secondary level and that teaching- and learning- materials were in short supply. There was a concern that teachers were under-qualified as in former African colleges of education (teacher training colleges), science and mathematics were low status subjects only taught at matriculation level to diploma pupils. Under-qualified and poorly prepared teachers in turn produce weak and poorly prepared school pupils. This cycle of mediocrity was also reinforced by the unsuitable nature of the science and mathematics curricula in the schools, which it claimed were academic, outmoded and overloaded. Applied science and technology as well as the social and ethical aspects of science were excluded from these curricula and the consequences of a lack of a suitable curriculum cut across racial divide. Ultimately prior to 1994, only 12% of higher education students pursued degree and diploma programmes in engineering and the life, physical and mathematical science and to date this position is relatively unchanged.

In recognition of these and other facts and the needs of this economically developing nation, the South African White Paper on Education (DoE, 1995)

[*] Reception year at school.

singles out mathematics as an important school subject. The White Paper recognises the importance of more pupils leaving school proficient in mathematics nonetheless, mathematics is only an optional subject from Grade 10 onwards.

The matriculation examination (the external national final examinations written at the end of grade 12) figures have been used as an indicator of South African pupils' performance at school level. The number of matriculants has increased rapidly alongside the changes in the political arena. In 1979 (SAIRR, 1997), there were 76 625 candidates for the Grade 12 examinations. Of these, 90% passed whilst 42% obtained matric exemption allowing them to enter university. The numbers of candidates rose rapidly and results changed as the number of African pupils gained access to the matriculation examination. In 1993, 470 948 pupils wrote the matriculation exams at the end of grade 12 and 58% of these passed (Education Foundation, 1994, p. 9). However, by 1998 the number of candidates had increased to 553 151 with only 51% of these passing the examinations again signalling a problem with both the efficiency and effectiveness of the system. (Education Foundation, 1999, p. 7). However, over the past few years, the matriculation results have seemed to stabilise and national improvements were recorded in 2000 and again in 2001 wherein 60% of the pupils passed. However, whereas more than 550 000 fulltime pupils wrote matric in 1998, in 2001 the number had dropped by 100 000. Possible reasons offered for this drop include population statistics, HIV and Aids and socio-economic problems.

To what extent the improved pass rates in 2001 can be attributed to actual improvements in performance is uncertain. What has happened that might explain the improvement is the following:

- the introduction of year marks (contributing to 25% of the overall matric marks) across the country;
- an additional 5% being awarded to pupils writing in a second language;
- the elimination of over-age pupils from mainstream schools;
- a dramatic decrease in the numbers of repeaters (down to 6 000 pupils in 2001) writing the examinations within schools;
- a higher percentage of pupils taking subjects on the standard grade resulting in more pupils passing overall;
- finally, the government also introduced a programme to address schools where less than 20% of their pupils had passed matric the previous year.

Some of these have probably also resulted in a dramatic decrease in the number of pupils writing matric.

Table 2.1
Number of fulltime candidates writing matriculation examinations

Year	Number of fulltime candidates writing matriculation exams
2001	449 371
2000	489 941
1999	511 574
1998	552 862

With regard to mathematics specifically, in 1993, of the 157 701 pupils who wrote the mathematics exam, only 80 050 (51%) passed. This represented 17% of the total number of candidates entering the matriculation exams in that year. In 1995, 47% of the candidates passed the mathematics examination. As Arnott and Kubeka (1997) reported that this poor performance "*was not a new trend and is largely a result of the low results achieved by African pupils who form the bulk of candidates. Since 1990, African matriculants have averaged 23% pass rate in mathematics…...; a lot lower than the total average for all races. In contrast between 1989 and 1993, white candidates in mathematics averaged 85% pass rate, coloured 59% and Indian 50%*" (p.20). By 1998, although the enrolment figure had increased by more than 120 000 pupils, the pass rate had dropped to 42% (DoE, 1999). However, the figures of 2000 reveal that 58% (430 005) of the 741 338 pupils that wrote the matriculation examinations enrolled for mathematics (DoE, 2000a). Of these only 45% passed mathematics on higher or standard grade. Of concern though is that fewer pupils are enrolling on the higher grade, which would allow them to further their studies in the scientific and engineering fields. The situation regarding the enrolments in mathematics and the matriculation exemption with these subjects also varies dramatically between ethnic groups. For instance, only 1 in 312 African pupils entering the school system leaves with physical science and mathematics as final year subjects as compared to 1 in 5 White pupils (Blankley, 1994). As data by racial group are no longer reported publicly, it is not possible to report on the current status quo in 2001. It appears however, that more African pupils are enrolling in these subjects, but there has also been a drop in the overall pass rate consistent with the earlier remarks by Arnott and Kubeka (1997).

2.5. LANGUAGE-IN-EDUCATION POLICY AND PRACTICE IN SA SCHOOLS

As indicated in chapter one, the issue of language in education is a very important one as will be elaborated further in the section. South Africa is a multicultural and a multilingual society. Eleven official languages are recognised and include Afrikaans, English, Ndebele, Northern and Southern Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa and Zulu. This provides great challenges to policymakers and practitioners and is a highly politicised issue. This section summarises the language-in-education policies prior to 1990 and discusses the changes during the 1990s. This is concluded by a description of the shifting demography of pupils and language practices in South Africa.

2.5.1 Language-in-education policies prior to 1990

Like so much of South Africa's history, different policies were applied to different race groups. The policy in previously Coloured, Indian and White schools has stayed much the same since 1910 with English and Afrikaans (previously Dutch) being the official languages of the Union of South Africa. This meant that either English or Afrikaans was used as the medium of instruction with the second language being taught as a compulsory subject for all pupils. However, in 1948 when the Nationalist Party came to power, the policy changed and English and Afrikaans-speaking children were separated and sent to different schools where their mother tongue automatically became the language of instruction. To date English-medium and Afrikaans-medium schools still exist with a few dual medium schools scattered around the country. A small number of these schools introduced African languages that were offered as an optional subject.

Regarding the coloured and Indian schools, the policy was similar to that of the white schools. Schools for Indians generally followed the English-speaking schools examples using English as the medium of instruction and offering Afrikaans as a compulsory subject. Only in the 1980's did some Indian schools start to offer their vernacular languages as part of the school curriculum. Coloured schools varied with some opting for English and others for Afrikaans as the medium of instruction and sometimes within one school both languages were used for instruction with pupils streamed for this purpose.

At the beginning of the 20th century, missionaries teaching in African schools used English as the medium of instruction, but after 1910 began to look for the introduction of African languages as subjects (following the example of Zulu being introduced into Natal African schools) and as medium of instruction. By the Second World War, the vernacular language was a compulsory subject in all primary schools and teacher training colleges and the medium of instruction in all four provinces (Cape, Natal, Transvaal and the Orange Free State) was the pupils' mother tongue. However, this was only in the first couple of years of primary school and this varied from the first two years to four to six years depending on the province. After these initial years, either English or Afrikaans were used as the medium of instruction, with the majority of schools opting for English.

The Nationalist Party's rise to power changed the policy and practice of language in education. Firstly African schools were placed under a centralised bureaucracy (Department of Bantu Education) away from the previously provincial administrations and secondly, the Bantu Education Act of 1953 changed the language policy to extend the use of the African languages and Afrikaans. Mother tongue was to be used for the first eight years of schooling (the whole of primary schooling) and English and Afrikaans became compulsory subjects from the first year of schooling. This change became the focus of the opposition to Bantu Education. "*Black opinion never became reconciled to the extension of mother tongue medium beyond Std 2* (now grade 4) *nor to the dual medium policy in the secondary schools*" (Hartshorne, 1992, p.198) and the change in policy was immediately met with opposition. However, it was not until the Soweto uprising in 1976, that this resistance to the language policies manifested itself openly.

With the introduction of and separate development of independent homelands and self-governing territories, the language policies evolved differently to the then government's expectations. These opted for mother tongue instruction in only the first four years of schooling from the 1960's and by 1974 all had decided (with one exception) on using only English as the official language of instruction from year 5 onwards. This resulted in the difference in policy between African schools under the homelands and self-governing territories and those under the National Department of Bantu Education. This coincided with the government's decision to change the years of schooling for African pupils from eight to seven years like the other race groups. The consequences of what appeared to be an obvious policy change was that pupils had to write their end of primary schooling examination in English or Afrikaans a year earlier with less exposure to these languages.

Thereafter, the resistance to the policy change came from junior secondary and senior primary schools culminating in the violence infamously known as the Soweto uprising of 1976 (as it started in Soweto). By mid-1976 the minister of education reverted the dual medium policy to a single medium of instruction to be decided by the school. The Education and Training Act of 1979, decreed that the medium of instruction should be mother tongue until year 5 of primary school and thereafter the parent of the pupils should decide. However parents resisted this mother-tongue requirement. The De Lange commission was instituted in 1980 by the Cabinet who requested the Human Sciences Research Council to conduct *an in-depth investigation into all facets of education in South Africa"* (HSRC, 1991, p. 5). The De Lange report, as it became known, incorporated the work of 18 committees and 1 300 people. One of the issues included in the investigation was that of the language issue. The commission offered three options including English instruction from first grade and although the report was submitted in 1981, the government chose to delay the implementation of the recommendations until 1990. This resulted in parents having the right to choose the medium of instruction at each school. The options available to parents of pupils at African schools were: start immediately with the medium of instruction to be used in the long term, a sudden transfer from the mother tongue to a second language medium or thirdly, a graduated transfer from the mother tongue to a second language medium. It would appear that the majority of schools adopted the first option of English as the language of instruction from Grade 1, although no audit has been conducted to substantiate the anecdotal evidence available.

2.5.2 Language-in-education policies after 1990

The 1990's saw a multitude of policy documents on language-in-education. Although there was widespread consultation, there was also increased debate on bilingualism and multilingualism. In general, the policy documents promote the concepts of multilingualism. The importance of all South Africa's languages is stressed and at school level, the documents promote bilingualism at the very least but prefer that pupils should learn at least three languages. The country's constitution asserts that the importance of creating conditions for both the development and promotion of all official South African languages in terms of equal use. The White Paper on Education and Training (DoE, 1995) states that the language in education policy allow for the pupil to have the right to chose their language of instruction where it is reasonably practical. However, neither the White Paper nor the Department of Education's Language in Education Policy (DoE, 1997b) places any pressure on the schools to offer particular languages. They only encourage schools, which are willing and able to offer more than one language medium to accommodate parents' or learners' preferences. Ultimately the decision on the languages of instruction and those offered as subjects is left to the school governing bodies. The Schools Act (1995) stipulates that these bodies are required to announce what the schools' language policy is and how it will promote multi-lingualism through various means.

The difficulty of this is that schools find themselves in a quandary as to how to introduce such changes with cuts in the education budgets, frozen posts and redeployment of teachers have left little space for schools to enter into new course directions. The absence of a concrete implementation strategy by the government means that in all likelihood, past practices will continue and the goal of a multi-lingual society will disappear.

2.5.3 Shifting demography of pupils and language practice

One of the most noticeable changes after 1994 was the dramatic change in the demography of pupils at previously white, coloured and Indian schools. African-language speaking pupils from the townships poured into all of these schools, whilst many Indian and coloured children moved into former white government schools. In areas like Johannesburg where the diversity of languages is vast, there are obvious consequences for instruction in the classrooms. One of the results of urbanisation, is that many pupils do not have an obvious primary language nor have the desire to identify with any one linguistic group (Brown, 1998; Pirie, 1984). Instead many pupils speak a number of languages and in some townships develop a dialect made up of words from a variety of African languages, English and Afrikaans. However, it is also true that they may not be fluent in all of these languages or even truly fluent in even one language.

The multicultural communities created by the dissolving of Apartheid and increased mobility of families seeking upward mobility means that issues around language in education are complex. Effective instruction is largely dependent on good communication under-pinned by competence by both teachers and pupils in the language of instruction. However, the reality is that this is a problem in the majority of schools where the language of instruction used and the mother tongue of the teachers and/or the pupils is different. The consequence is that pupils' achievement in mathematics and other subjects could be negatively affected.

CHAPTER 3
Research into pupils' achievement in mathematics

*In recent years much attention has been given to monitoring of educational achievement. Several studies have investigated factors influencing achievement of pupils especially in mathematics, however not many of these studies were found in developing countries. South Africa participated in three IEA international studies of which two are concerned with pupils' performance in mathematics and science conducted in 1994/1995, known as the Third International Mathematics Study (TIMSS), and this repeated in 1998/1999. One of the most important factors believed to influence South African pupils' performance is language as more than 70% of the pupils had written the TIMSS-*R *test in a second language. Much has been written about what influences pupils' achievement in general. Factors can be divided into those on student, classroom and school level that have an effect on achievement in mathematics. There are also a number of differences between the factors affecting the achievement of pupils in developed as opposed to those in the developing countries.*

3.1 INTRODUCTION

The aim of this study is to describe the performance of South African grade 8 pupils in mathematics within an international perspective and to explore the relationship of mathematics achievement with pupils' proficiency in English as well as other background variables. Several studies have investigated factors influencing the achievement of pupils especially in mathematics, however not many of these studies were found in developing countries. The purpose of this chapter is to present a review of the literature on key issues related to the central research problem. Its functions are to inform the study about what is already known from research related to these key issues, as well as to be a stepping-stone towards the conceptual framework for the description and analyses in this study.

Firstly, South Africa's participation in international studies is discussed especially the performance in the Third International Mathematics and Science Study (TIMSS) conducted in 1995 (3.2). One of the most important factors believed to influence South African pupils' performance is language and the literature relating to this topic is discussed (3.3). Much has been written about what influences pupils' achievement in general (3.4). Factors can be divided into those on student, classroom and school level that have an effect on achievement in mathematics. There are also a number of differences between the factors affecting the achievement of pupils in developed countries as opposed to those in the developing countries which are also summarised here. Finally, the factors that are included for further analysis of the TIMSS-R(epeat) are briefly discussed in 3.5.

3.1.1 South African pupils' performance in mathematics

There have been a number of reports and articles written on the status of mathematics (and science) education in South Africa (Arnott & Kubeka, 1997; Kahn, 1993; Taylor & Vinjevold, 1999; amongst others). Many have bemoaned the poor results achieved in the mathematics matriculation examinations (see chapter 2). However, there have been no national surveys on pupils' achievement in mathematics conducted by the Department of Education or other government departments. Only in 2001, was the decision made to introduce sample-based national assessments at grades 3, 6 and 9 levels to provide policymakers with information regarding the effectiveness of the education system. Research conducted that included achievement data were case studies on local and regional samples (see Maja, Swanepoel & Du Toit, 1999; Monyana, 1996; Rakgokong, 1994; amongst others), which were not nationally representative samples resulting in limited inferences being made from the data. Any national achievement data collected so far have been part of an international study such as TIMSS 1995, TIMSS-R, MLA or SACMEQ, which are discussed in the next section (3.2).

However, a number of factors have been reported pertaining to the poor performance of pupils in the matriculation examinations and in general (Arnott & Kubeka, 1997; Kahn, 1993; Monyana, 1996; Taylor & Vinjevold, 1999). These include the following:

- inadequate subject knowledge of teachers
- inadequate communication ability of pupils and teachers in the language of instruction
- lack of instructional materials
- difficulties experienced by teachers to manage activities in classrooms

- the lack of professional leadership
- pressure to complete examination driven syllabi
- heavy teaching loads
- overcrowded classrooms
- poor communication between policy-makers and practitioners
- lack of support due to a shortage of professional staff in the ministries of education.

These were reported on the basis of classroom observations and discussions with teachers and other stakeholders. Only Monyana (1996) collected data for the purpose of analysing the factors that had an effect on mathematics performance and utilised inferential statistics. Currently there is a study involving data from 100 schools as part of the Quality Learning Project that has also collected background data in order to infer reasons for pupils' performance in mathematics (and science) (see Prinsloo, Kanjee, Pfeiffer & Howie, 2001).

In section 3.4 the discussion of factors influencing achievement will be elaborated further.

3.2. South African pupils' performance in international comparative studies

South Africa has only recently joined a number of international comparative studies in education. Two of these have focused on primary level, Monitoring Learning Achievement (MLA) and Southern Africa Consortium for Monitoring Educational Quality (SACMEQ) and two focused on secondary level (TIMSS and TIMSS-R). In this section, first a brief reference is given to the South African participation in MLA and SACMEQ due to the fact these studies were at primary level and no results are reported early 2002. Then TIMSS 1995 is discussed more substantially as it is the predecessor of TIMSS-R. Given that TIMSS-R is the focus of this study it will be extensively discussed in Chapter 4.

3.2.1 SACMEQ and MLA

SACMEQ, the Southern Africa Consortium for Monitoring Educational Quality, was initiated in 1991 when a number of Ministries of Education in the Southern Africa Sub-region started working together to address the need for systematic studies of the conditions of schooling and of student achievement levels. The focus of this work was to establish long-term strategies for building the capacity of educational planners to monitor and evaluate basic education systems.

The first two SACMEQ projects (SACMEQ I and SACMEQ II) focused on an assessment of the conditions of schooling and the quality of education and included achievement data on reading literacy. South Africa only participated in SACMEQ II, which commenced in mid-1998. Data were collected in late 2000 and were not yet reported by early 2002.

MLA began in 1992 and was a joint project of UNESCO and UNICEF. The aim was to examine the effectiveness of the basic education provision in terms of actual learning attainment (Chinapah et al., 1999, p. vi). The project forms part of the Education for All initiative. Learning attainment of Grade 4 pupils was measured by means of achievement scores in literacy, numeracy and life skills and a criterion-referenced approach was used. Although the report published included all the participating African countries, the South African government refused permission for the South African data to be included in the African report whereby the South African pupils' performance could be compared. Instead a separate confidential report was compiled and revealed that the South African pupils' performance was well below that of their counterparts in Botswana, Madagascar, Malawi, Mali, Morocco, Mauritius, Niger, Senegal, Tunisia, Uganda and Zambia. At this stage it is not clear how comparable the data are across countries.

3.2.2 The Third International Mathematics and Science Study (TIMSS)

The International Association for the Evaluation of Educational Achievement (IEA) conducted the Third International Mathematics and Science Study (TIMSS) between 1990 and 1995, which was repeated as TIMSS-R(epeat) in 1998 (southern hemisphere countries) and 1999 (northern hemisphere countries). Where TIMSS-R is the focus of this study, it is important to discuss the key results for South Africa from the TIMSStudy in this section to the extent that they are important for the research problem to be addressed.

In 1995 the Human Sciences Research Council (HSRC) conducted TIMSS South Africa. Although TIMSS internationally included three student population groups, funding constraints prevented South Africa from participating in all of them. More than half of population 1 (being grades 3 and 4 pupils in primary education) was studying in their mother tongue and it was too expensive to administer tests in different languages. As a result South Africa only participated in population 2 and 3.

Population 2 consisted in South Africa of grades 7 and 8 pupils, whilst population 3 consisted of grade 12 pupils who were in their final year of formal schooling.

A randomly selected national sample of schools, representative of all provinces, race groups, urban and rural, was identified. The sampling was strictly controlled and TIMSS-South Africa was assisted by the international study group to ensure the statistical validity of the study (Howie, 1997).

The TIMSS research in South Africa consisted of three components: the curriculum analysis, achievement tests and questionnaires. Researchers and department of education officials conducted the curriculum analysis (see Schmidt, McNight, Valverde, Houang & Wiley, 1997, for details of the mathematics curriculum analysis). The curriculum guides and the most frequently used textbooks in mathematics, science and geography were analysed. South Africa did not participate in the performance tasks designed to assess those mathematical and scientific skills and abilities of pupils that could not readily be assessed in a written test.

Fifteen thousand South African pupils from more than 400 primary and secondary schools participated in TIMSS 1995. Out of 41 countries South Africa was the only African country to have participated. Data from only 4 491 grade 8 pupils from 114 schools and 5 301 pupils in grade 7 from 137 schools were included for analysis in the study (Howie, 1997). For grade 12, only 2 757 pupils from 90 schools were included in the analysis (Howie & Hughes, 1998). The grade 12 pupils (population 3) wrote the general mathematics and science test that centred on literacy in these subjects. This was in contrast to the curriculum-driven test, which was administered to the grades 7 and 8 (population 2).

Major findings for TIMSS-South Africa

In general, the overall South African results for Grades 7 and 8 and for Grade 12 pupils were very low in comparison with other countries (and were the lowest of all countries participating in both population groups). This is also true for the results in mathematics (and science) separately for all three grades. South Africa was one of a few countries where gender did not play a significant role with regard to the results. The findings given in this section are drawn from the South African reports (Howie, 1997; Howie & Hughes, 1998) as well as from the international reports (Beaton, Martin, et al., 1996; Beaton, Mullis, et al., 1996). As mathematics achievement is the focus of this research, the focus will be on the mathematics and not the science achievement.

Table 3.1
South African mathematics results compared to selected countries

Country	Grade 7		Grade 8		Grade 12	
	Mean	*Std error*	*Mean*	*Std error*	*Mean*	*Std error*
Australia	498	3.8	530	4.0	522	9.3
Japan	571	1.9	605	1.9		
Netherlands	516	4.1	541	6.7	560	4.7
USA	476	5.5	500	4.6	461	3.2
Czech Rep	523	4.9	564	4.9	466	12.3
Hungary	502	3.7	537	3.2	483	3.2
Slovenia	498	3.0	541	3.1	512	8.3
South Africa	*348*	*3.8*	*354*	*4.4*	*356*	*8.3*
Bulgaria	514	7.5	540	6.3		
Iran	401	2.0	428	2.2		
Russian Fed	501	4.0	535	5.3	471	6.2
Thailand	495	4.8	522	5.7		
International average	**484**		**513**		**500**	

Grade 7 and 8 mathematics results

TIMSS test results are scored on an 800-point scale with an average of 500 points and a standard deviation of 100. The South African Grade 7 and 8 pupils' performance in mathematics was slightly better (348 and 354) than for science, although it was still well below the international means (484 and 513) (see Table 2). There was no significant difference between the results of the South African Grade 7 and Grade 8 pupils in mathematics unlike the results of their peers internationally. The performance of Grades 7 and 8 pupils on the mathematics questions covered by the curricula was comparable to those that were not in the curricula. In total, 50% of the items were found in the Grade 7 mathematics curriculum and 80% of the items in the South African Grade 8 mathematics curriculum.

The performance of the South African pupils was uniformly poor across all the content areas in mathematics in both grades. In mathematics, pupils in both grades achieved the lowest percentages correct in measurement, followed by proportionality (18% and 17% respectively).

Grade 12 mathematics literacy results

South Africa was the only industrially developing country in the Grade 12 study from Africa, Latin America or Asia. The literacy test was given to all pupils in the sampled grade 12 classes, regardless of whether they took science and mathematics as subjects. The performance of South Africa's top performing pupils was not comparable to the top performing pupils of other countries. The performance varied considerably across different provinces in South Africa. Pupils from the two most economically impoverished provinces, which also have the greatest number of under-resourced schools, performed worst in the final year pupils' mathematics literacy test and overall.

Grade 12 pupils with English or Afrikaans as their home-language (the languages of instruction and hence the languages of the test) performed better (although still below the international mean) than those speaking another language at home. South African pupils in both studies struggled with the free-response questions and appeared unable to formulate their own answers. South Africa was the only country where the language of the test was not the home language of the majority of pupils and there was evidence amongst the pupils from all three grades of language difficulties.

Some conclusions

The results highlighted the disparities in the schooling systems with pupils in schools from traditionally disadvantaged areas achieving lower scores than pupils from schools in more advantaged areas, although exceptions were found for individual scores. These differences can be partly explained by unequal provision of resources and facilities in the past; different socio-economic backgrounds, as well as, the variation of pupils' home languages.

In both populations 2 and 3 studies, pupils were older than their international counterparts in TIMSS. In Grade 7, South African pupils were 13.9 years and in Grade 8 they were 15.4 years compared to the international averages of 13.2 years and 14.2 years. The South African Grade 12 pupils were 20.1 years of age compared to the international average age of 18.6. Given the high numbers of pupils repeating grades in South African schools, this was not surprising. In the Grade 12 sample, more than 16% of the pupils were repeating Grade 12 and yet they were still in a mainstream school.

South African pupils' parents' education levels were found to be very low. More than 30% of the South African pupils' parents' had completed primary school only and had not progressed further and this may also explain why in South Africa, that the average number of books in the homes of pupils in both studies was substantially less than the international average.

At schools, South African Grade 7 and 8 pupils had less learning time than pupils in the top-performing countries and the amount of homework given to Grade 7 and 8 pupils was much lower than the international average.

The attitudes of the South African pupils towards mathematics were generally positive for all three grades, perhaps more so than expected. It was also interesting to find that pupils in all three grades felt that they normally performed well in this subject contrary to their results in TIMSS.

There were significant language and communication problems with South African pupils learning mathematics in a second language. Pupils in all three Grades showed a lack of understanding of both mathematics questions, and an inability to communicate their answers in instances where they did understand the questions. Pupils performed particularly badly in questions requiring a written answer.

A very high percentage of pupils (75%) indicated that they intended going to university after school, which appears to be completely unrealistic, given the generally low levels of mathematics literacy and achievement at school. However, what it also indicates is the lack of career guidance from schools as well as the overemphasis on university-type education at the expense of more suitable occupations for pupils of differing aptitudes.

Main findings of the Curriculum Analysis

South Africa also participated in the curriculum analysis aspect of TIMSS (Schmidt, McKnight, Valverde, Houang, & Wiley, 1997). The curricula from both primary and secondary school were analysed. South Africa was found to be very similar to most other participating countries with respect to the entry age of pupils, the number of years of compulsory schooling and the length of schooling time. However, there were obvious differences with respect to both the curriculum guides and the mathematics textbooks. For example, the South African guides contained the highest proportion of content of all the countries. The main areas excluded from the guides were *estimation and number sense concepts*, *transformations* and *uncertainty and probability*. In the South African textbooks, low proportions of activities and assessment suggestions and a relatively high proportion of exercise blocks were found. As far as performance expectations were concerned, the South African textbooks focused primarily on the lower order skills such as *knowing* and *using routine procedures*. Paradoxically, there was a relatively high emphasis on the highest order skill *mathematical reasoning*. Finally, South African textbooks contain almost nothing on promoting positive attitudes towards mathematics and in particular, do not increase the pupils' awareness of the relevance of these subjects to the world outside the classroom.

3.3 THE IMPACT OF LANGUAGE ON MATHEMATICS ACHIEVEMENT

In Chapter 2, some of the main points of the Language-in-education policy were summarised. In this section, the emphasis is given to the research conducted on the effect of language on mathematics in South Africa and internationally. Thereafter, some conclusions are drawn that are relevant for this study.

With 11 official languages in South Africa recognised by the New Constitution of South Africa, the language of instruction is a complex and sensitive issue. Faced with the overwhelming problems of reconstructing the education system, language in education has been somewhat neglected (Heugh, 1999; Webb, 1999). This is problematic given the significant increase in the number of African language speakers enrolled at school over the past 20 years. Moreover there is evidence of failure at the matriculation level and that 80% of the pupils' languages at home are other than English (Heugh, 1999, p. 302).

Officially, the national Department of Education has given its commitment to a new language-in-education policy that reflects values, which are consistent with the Constitution. However, despite the open commitment to a new language-in-education policy, there is still no indication of how such a new multi-lingual policy will be implemented in the schools. For all practical purposes, the languages of instruction are still English and Afrikaans at school from grade 5 onwards, although it is common practice in South African schools for teachers and pupils to switch between these and African-languages in the classroom. The President's Education Initiative (PEI) research (see Taylor & Vinjevold, 1999) suggested that few schools have developed formal language policies. The researchers found that learning through the primary (home) language in the early years of schooling is on the decrease. Parents see English as a means to social and economic advancement and as a language of power. As a result they are putting pressure on schools to offer English as the language of learning from the onset of schooling and send their children to pre-primary schools where English is spoken.

In South Africa, much of the research into language and its effect on mathematics has focused on primary level (Adler, 1991; Du Toit, 1991; MacDonald & Burroughs, 1991; Olivier, Murray & Human, 1990; Rakgokong, 1994; amongst others). Pupils change from learning in their main language to learning in either English or Afrikaans in Grade 5. Although English and Afrikaans are introduced already in grade 2 as a subject, if children do not speak these at home, the skills of the pupils' main language and the additional languages are not well developed. This means that their spoken fluency and writing skills are limited and are not *"sufficient such that the pupils can handle subject matters with it*" (Rakgokong, 1994, p. 434). African languages are very different linguistically from the English and if pupils have not developed sufficiently in both languages they may experience serious learning problems.

The importance of verbalisation in the formation of mathematical concepts has been highlighted by Aoyles (1985), Morrow (1985), Taylor (1988) amongst others. Several researchers have uncovered these problems encountered by pupils when learning in a secondary language (Berry, 1985; Bishop, 1985; Brodie, 1989; Dawe, 1983; Joint Education Trust [JET], 1998; Setati, 1999).

A literature survey by the Joint Education Trust (1998, p. 24) on teaching in multi-lingual classrooms revealed that in South Africa, Afrikaans/English dual medium schools facilitate second language learning and encourage communication and cultural exchange, and that children in dual medium classes show better progress than children who are taught through one medium only. However, the same survey found that research on subtractive bilingual programmes in black schools revealed that not only did pupils resort to rote-learning content that they did not understand, but that pupils also failed to achieve adequate levels of academic language proficiency in both their main language and English. Language plays an important role in the formulation and expression of concepts in mathematics. Colyn and Lebethe (in JET, 1998, p. 23) attribute a lack of confidence and unwillingness by pupils in using mathematics language to the fact that the language is often meaningless to them. This they say is because of the use of familiar words in unfamiliar contexts; the ambiguity of the language of mathematics; and the fact that pupils' informal language is much more developed and complex than their mathematical language. This has serious implications generally for the achievement of second-language speakers and in particular, for their performance in mathematics.

International Perspective

It is not only South Africa that experiences problems with language and learning. All post-colonial countries struggle to reconcile the former colonial power's legacy of language (English, French and Portuguese in Africa) with the indigenous cultural needs as well as the desire to be part of the global economy which increasingly requires English to be spoken. In the Second International Mathematics Study, Garden and Livingstone (1989, p. 26) found that the majority of pupils in a number of countries (including other African countries of Swaziland and Nigeria) in that study received their instruction at school in a different language from that used at home.

There has been extensive research internationally on the effects of bilingualism. A number of methodological problems have also been reported (Baker, 1996; Baker & Prys-Jones, 1998; Clarkson, 1991; Clarkson, 1992; Cummins, 1986; Ellerton & Clements, 1991; Garcia 1991; Garcia & Baker, 1995; Gardner, 1979; Giles & Bryne, 1982; Giles & Coupland, 1991; JET, 1998; Lambert, 1974; Schumann, 1978) amongst others). These include the confounding of bilingualism and socio-economic status, the degree of bilingualism, the degree of difference between two languages, and the age at which the second language is learned (Garden & Livingstone, 1989, p. 26).

Baker and Prys-Jones (1998) identified 10 different types of bilingual education, which they classified into weak (6 types) and strong forms (4 types) of education for bilingualism. The idea behind the weak form of bilingual education is that the education programme will contain bilingual children but that the aim of the programme is often "*to produce monolingualism or limited bilingualism rather than true bilingualism*". In contrast the strong form of bilingual education's aim is "*to produce students who are proficient in two languages and biliterate as well*" (Baker & Prys-Jones, 1998, p. 469). Furthermore, the strong forms of bilingualism are generally intended to maintain a language minority and to create cultural pluralism and multiculturalism within the child and society. Baker and Prys-Jones build on the work of Mackey (1970) who identified 90 different varieties of bilingual schooling who considered a number of contextual variables to categorise these, whereas Baker and Prys-Jones reflected on the aims of the education itself.

A number of models attempting to explain the concept of bilingual education have been developed (Baker, 1985; Dunkin & Biddle, 1974; Stern, 1983; are but a few). Typically in these models, four main factors, namely inputs, processes, outputs and contexts are related and integrated. Much research has focused on the relationship of the inputs (such as pupil's language or teacher characteristics) to the outputs. Baker and Prys-Jones integrated these four main factors, namely, inputs, outputs, contexts and processes to develop an organising framework for thinking about bilingual education (1998, p. 473-475).

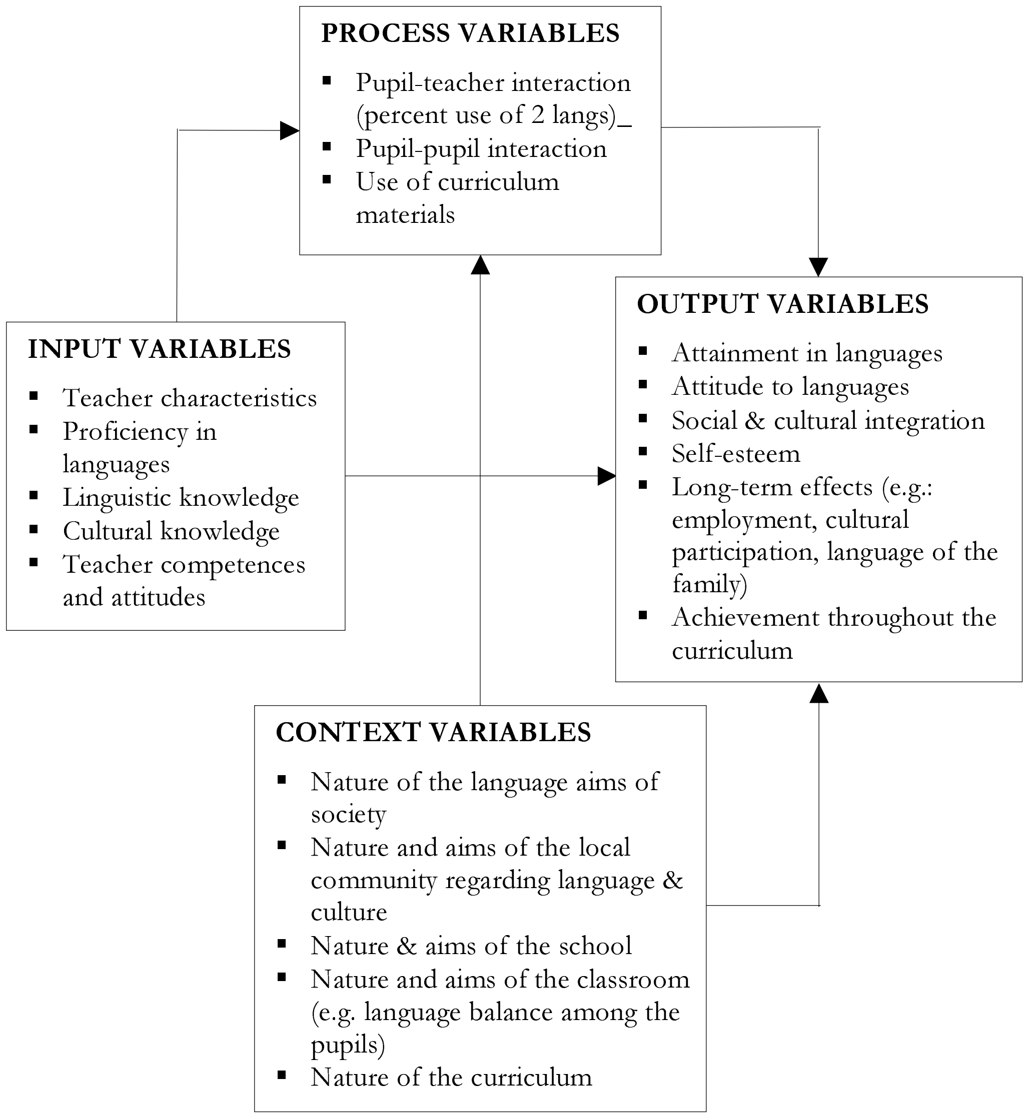


Figure 3.1
Input-Context-Process-Output Model of Bilingual Education (Baker & Prys-Jones, 1998)

South Africa like many other multi-lingual societies, has a responsibility to all the languages of its people. Most South Africans speak at least two languages, but many African people speak four or five languages including English and Afrikaans. However, it is unusual for many native English or Afrikaans-speaking people to speak African languages fluently. The exceptions are often people who have grown up in rural areas.

The South African situation can be illustrated by means of this model (see Figure 3.1). In the model, it is clear that the input, process and context variables all contribute to the output variables. With a closer look at the input variables within the South African context, one can already see where some of the problems may lie in preventing the successful accomplishment of the output variables such as attainment in languages. The many teachers in multi-lingual classrooms are limited in their proficiency of languages other than their main language. Many only have a limited grasp of one other language and may struggle when having to teach in English or Afrikaans. Alternatively many native English or Afrikaans-speaking teachers cannot speak an African language and therefore cannot communicate and clarify concepts in a pupil's main language when this is an African language. Due to the separation of the races under Apartheid, the majority of adults have little cross-cultural knowledge and therefore simply do not understand other cultures. Much has already been said in chapter 2 about teachers and their competencies and attitudes. In South Africa, many teachers are under-qualified and suffer from low morale. All of these input variables have an impact on the pupils' language attainment.

If one looks at the process variables, it is also obvious where problems could arise. If teachers cannot interact fluently with their pupils and *vice versa*, then learning is difficult and may be obstructed. Likewise in multi-lingual classrooms difficulties can arise between pupils during group work and also when using curriculum materials which the pupils struggle to engage with.

The context variables are equally important as they also influence the process variables in addition to influencing the output variables. The intentions of the society, the local community, the school, the teacher in the classroom, all have an effect on the learning outcomes. The nature of the curriculum is also important. Therefore if there is no direct guidance from policymakers on the implementation phase of language-in-education policies then this too has an effect on the outcome. For instance, it may be the desire of the community and policymakers that children in South Africa should be exposed to and have a minimum language proficiency or conversational skills in at least three (two languages in addition to their own) of the 11 official languages. This could be enforced and implemented through the curriculum, which will have an impact on factors such as pupils' attainment in languages, their attitude to languages, their social and cultural integration (through knowledge and understanding), self-esteem, long-term effects such as employment (the latter is very important in South Africa where most companies require a minimum bilingualism and increasingly this includes an African language) and achievement through the curriculum.

A review of the literature reveals different schools of thought on the age and stage of development by which a second language should be introduced or by when the language of instruction should be changed. These have been informed by various cognitive theories of bilingualism and the curriculum such as the Balance Theory, Iceberg Analogy, and the Thresholds Theory (Baker & Prys-Jones, 1998, pp. 74-80). A discussion of all of these goes beyond the scope of this dissertation, but for a more comprehensive overview of these and others, see Baker and Prys-Jones' Encyclopedia of Bilingualism and Bilingual education (1998). However, just to give an example of the challenges found to be facing children's learning in a second language, Cummins (1981, 1986) concluded that it often takes one to two years for a child to acquire context embedded second language fluency, but five to seven years (or longer) for them to acquire context reduced fluency. Therefore whilst children with some conversational-level ability in a second language may appear to be ready for instruction in a second language, this is not necessarily the case as they lack the context-reduced fluency. In essence, children at this level may fail to understand the curriculum content and will therefore fail to engage in higher order cognitive processes in the classroom (e.g.: synthesis, discussion, analysis, evaluation and interpretation).

In South Africa, Berry (1995) suggested that fluency in the second language does not guarantee success in maths and Dawe (1983) found that whilst English second language may be a problem in mathematics, reasoning factors like linguistic distance and culture are also important in bilingual children's achievement. According to Austin and Howson (1979) bilingualism can hamper performance of pupils in problem solving but not necessarily in procedural arithmetic. However, Rakgokong (1994) concludes differently. Rakgokong tested 60 first language Setswana pupils who answered the maths test in Setswana only, or English only or a combination of English-Setswana. The findings indicated that, "*second language does not hamper the pupils' progress in problem-solving only, but also in procedural understanding of division in a test, even though it involves minimal language*" (p.440).

It is not only pupils that struggle with the language. Many teachers who speak one of the African languages at home are not fluent in the language of instruction. Likewise most teachers who are native English or Afrikaans speakers cannot speak an African language and therefore struggle to communicate with children in multilingual classrooms. Setati's (1999) study of six teachers revealed that the mathematics teachers had different understandings of the official language policy. All of them (spoke an African language at home) felt that English was important.

However, four of the six used code switching and Setati (1999) concluded that the absence or limited use of code switching constrained the mathematical discourse and led to a limited use of mathematical discourse in the classroom. She believes that the use of code switching facilitated pupils' engagement in both the calculational and conceptual discourse which many of them could not have done only in English.

Ultimately, it appears that language does have an effect on achievement (Austin & Dawe, 1983; Berry, 1985; Clarkson, 1991; Tatre & Fennema, 1995; Young, 1997; amongst others). For instance, Tartre and Fennema (1995) found that in addition to spatial visualisation, verbal skills were related to achievement. In her research on rural Australian children especially those from an Aboriginal background Young (1997) found that there was a positive effect on achievement of speaking English at home . However, it is not clear in her research as to whether boys and girls perform differently. Although Hyde and Linn (1988) report in their meta-analysis of the studies of gender difference in verbal ability that there was no gender difference in verbal skill, other studies show significant differences in performance in reading and writing skills favouring girls (see for instance Elley, 1992). Elley reported that out of 32 participating countries, girls outperformed boys in every country in a study of reading literacy (1992, p. xii).

Whilst researchers and others still disagree on when and how pupils should be introduced to or learn a second language, there does seem to be some consensus that additional languages enrich pupils' own main language and contribute to other important societal goals such as understanding different cultures. Nevertheless, when pupils are compelled to learn through a second language, this can become a serious obstruction in the pupils' learning process for various reasons described earlier. However, although language clearly matters and has an effect on pupils' performance in mathematics, this is only one of a number of potential factors having an effect on children's learning and performance. Some of these other factors are described and discussed in the next section.

3.4 FACTORS INFLUENCING MATHEMATICS ACHIEVEMENT

The primary purpose of this section is to identify which factors may potentially influence mathematics achievement of South African pupils. Previous research shows that there are many factors at different levels that influence achievement in general, and mathematics achievement specifically. In this section these are discussed at student, classroom and school-level as these are the three levels that were included in the analysis of the TIMSS-R data.

The majority of research in this area has been carried out in the context of industrialised, developed countries. Yet relationships between variables/ factors and mathematics achievement found in such countries are also of interest for analysing similar relationships in South Africa and other developing countries: whether the same, different or no relationships will be found, the results contribute to the body of knowledge that is the focus of this study. Thus, this section summarises the most important factors identified in previous research as influencing (mathematics) achievement, and where appropriate reference to the context of certain countries or of developing countries will be made.

3.4.1 Factors on student level influencing achievement

Home background and community factors

In general, *home environment* has been found to have positive relationship with mathematics achievement (Benbow, Arjmand & Walberg, 1991; Campbell & Mandel, 1990; Kaiser-Messmer, 1993). Specifically several studies revealed that *socio-economic status (SES)* had a significant relationship with achievement in mathematics (Afrassa, 1998; Cherian, 1992; Hafner, 1993; Howie & Pietersen, 2001; Kohr et al., 1989; Luyten, 1994; Maqsud & Klalique, 1991; Mohandas, 1999; Mullis, 1992; Smith, 1994) and children from wealthier homes in general achieved higher scores for mathematics. Sojourner and Kushner (1997) found that in fact SES was the most consistent predictor of mathematics achievement of all the factors they examined in their study of more than 1 500 African Americans. However, there are a few studies that revealed findings to the contrary. Wong's (1992) study in Hong Kong found that materialistic family support and residential size did not play a dominant role in determining achievement. An Australian study (Young, 1997) conducted on children from rural and remote areas, found that the SES effect was weak, although positive. However, in South Africa a study by Monyana (1996) revealed no significant difference between children from different SES backgrounds. Vari (1997) had a similar finding when he reported that "economic capital" had no effect on Hungarian pupils' achievement in mathematics (p.95)

The *number of books* in the home is an important variable and although often associated with higher SES this is not a necessary condition. On the other hand, in TIMSS the number of books was used as a proxy for SES. Several studies have found a positive relationship between the number of books in the home and the pupils' achievement in mathematics (Martin, Mullis, Gregory, et al., 2000; Shen, 2000) amongst others).

The *education of parents* and the *occupation* of the parents have also been linked to achievement (Afrassa, 1998; Eshetu, 1988; Gennet, 1991; Howie & Pietersen, 2001; amongst others). Afrassa (1998) found a strong relationship between the mothers' and fathers' years of education and achievement of 13-year-old pupils in Australia in the Second International Mathematics Study (SIMS). He found that parental level of education (not the number of literate parents with a low level of education) had a strong positive influence on the degree of academic success of pupils. This was confirmed by Gennet (1991). Vari (1997) reported that "cultural capital" (comprising parents education, books in the home and family expectations) had a positive significant effect on achievement in Hungary. Bradford (1995) reported that educational resources in the home had a positive effect on pupils' mathematics achievement. An investigation by Campbell (1997) of participants in the Mathematics Olympiad (making them top achievers in mathematics amongst their peers) revealed that their families supplied higher levels of psychological support and intellectual resources and low levels of monitoring and the least pressure and help than those of the lower achievers. Clearly the relationship between the parents and the children is an important aspect. Eshetu (1988) found that those children who had a good relationship with parents also had higher scores in mathematics.

Parental press is also positively related to pupils' performance in mathematics, as has their *self-concept*, their *self-press* and *pupils' attitudes* towards maths achievement (Dickens & Cornell, 1993; Klebanov & Brooks-Gunn, 1992; Reynolds, 1991; Wong, 1992). A positive link was found between parental attitudes and achievement of their children, parental aspirations and achievement, although moderate it was positive for grade 8 pupils (Reynolds, 1991). Maqsud and Khalique (1991) and Dickens and Cornell (1993) also found a positive relationship between parents' self-concept in maths and their children's achievement in mathematics. Bradford (1995) found that if parents set high academic goals for their children and discussed their children's progress with them and attended school events, this tended to have a positive effect on achievement. Choppin (1967) concluded that the traditional expectations of those who stay in school and those who leave school helps to determine parental attitudes, pupil motivation and hence the performance at age 13. He felt that traditional expectations of success and failure in life as a whole may motivate some children more than others. No recent study was found that either confirmed or contradicted this important issue linked to social class.

The *size of the family* also has an effect on pupils' achievement in mathematics. Smaller families were found to be linked to better performance (Behutiye & Wagner, 1995), and Teshome (1993) found that pupils with a large number of siblings were hindered in their academic achievement. Berhanu (1986) confirmed that high achievers most often came from smaller families, whilst some studies showed that family size was significantly negatively correlated with better performance in mathematics (Cherian, 1992; Scott & Monteith, 1987). Parcel, Nickoll and Dufur (1996) concluded in their study of 1067 9-12-year-old children of working and non-working mothers that in addition to the number of siblings in the family, the fact that the mother was married as well as the number of hours that the spouse worked and their hourly wages were all factors that affected the mathematics outcomes (p. 461-483). In contrast, Lockheed (1990) found no relationship between family size and pupils' achievement in mathematics amongst Brazilian pupils.

In Africa and many developing parts of the world especially, children often are expected to complete a *number of jobs* around the house both before and after school (Afrassa, 1998). These often include collecting firewood and water, looking after younger siblings and cooking and cleaning in the house for the girls while boys often look after the animals. Pupils are burdened with lots of tasks in the lower grades (Damtew, 1972), which was confirmed by Deresse, Wagner and Alemaychu (1990). This has also been given as a reason for the lower performance of girls in South Africa as they are constantly expected to help at home (Daniel, 1995) and therefore girls have less time for their studies.

Whilst *parental aspirations* were found to be important, *pupils' aspirations* were significantly and positively correlated (especially career aspirations) with mathematics (Bradford, 1995; Norman, 1988; Shen, 2001). In a multi-level analysis of the TIMSS 1995 data of 18 countries, educational aspirations was found to be a significant predictor for 17 countries (the exception being Hong Kong). It was the most commonly found predictor out of 14 predictors included in the model (Martin, Mullis, Gregory, et al., 2000, p. 88).

Peer group attitudes to maths were found to be significantly linked to pupils' performance in mathematics by Dungan and Thurlow (1989), Maqsud and Khalique (1991) and Reynolds (1991). *Peers' perceived usefulness* of maths also resulted in males' stronger self-concepts than females and therefore stronger performance (Brandon et al., 1987; Campbell & Mandel, 1990; Kaiser-Messmer, 1993). Finally, *peer encouragement* had a positive relationship with pupils' mathematics performance (Nichols & Miller, 1994; Pyle, 1994; Webb & Farivar, 1994).

Personal factors

A South African study found that *personal variables* correlated more highly (positively and significantly) with maths achievement of secondary school pupils than teacher variables (Monyana, 1996), which was also found to be the case by Howie and Wedepohl (1997) using the South African grade 8 TIMSS 1995 data. Monyana (1996) also found that *pupils' self-concept* was the most significant variable in contributing to achievement in the South African study, whilst others (Bester, 1988; House, 1993; Marsh, 1989; Mullis, 1991; Randhawa et al., 1993; Valas & Sovik, 1993; Wong, 1992) have found a positive relationship with mathematics performance. In another study in China, *self-expectation* was found to be the most influential factor in maths achievement (Wong, 1992), but Reynolds (1991) and House (1993) found no effect on achievement with this variable. Birenbaum and Kraemer (1995) conducted a study of Jewish and Arab pupils looking for causal attributions of success and failure in maths and language exams. The results indicated significant and relatively large main effects for ethnicity and no significant main effects for gender. Large ethnic differences were found with respect to Hebrew and Arabic compared to Mathematics and English. Among nine specific attributions, ability was seen as the most prominent.

The relationship between *pupils' anxiety* with regard to mathematics and the corresponding negative significant relationship with mathematics is a well documented one (Birenbaum & Gurvirtz, 1993; Gliner, 1987; Hembree, 1990; Maqsud & Khalique, 1991; Meece et al., 1990; Nimer Fayez, 1990; Tocci & Engelhard, 1991; Wither, 1988; Wong, 1992). Several studies have also reported on the positive relationship of pupils' *enjoyment* of the subject and their achievement (Arnold, 1995, Garofalo, 1989, Mudeliar, 1987, Sayers, 1994, Wither, 1988) as well as the effects of pupils' positive *attitudes* towards maths and a corresponding positive relationship with performance (Arnold 1995; Baker & Jones, 1993; Bradford, 1995; Cheung, 1988; Marsh, 1989; Mullis, 1991; Reynolds & Walberg, 1992; Sojourner & Kushner, 1997). Schiefele and Csikszentmihalyi (1995) observed a positive relationship between the pupils' *interest in mathematics* and their achievement. It should however be noted that Norman (1988) found no such relationship between *attitudes* and achievement. An interesting finding by Ma (1995) indicated that low achievers developed a self-concept, which reflected a learned helplessness that had evolved over time, which in turn had a negative influence on their performance in mathematics.

Most recently, a study by Van den Broeck and Van Damme (2001) revealed that the most significant factor predicting the achievement of Belgian grade 8 pupils is their *cognitive ability*. This was also reported earlier by Vari (1997) from his study in

Hungary and also by a study in South Africa (Gordon, 1979) that examined the role of cognitive and attitude variables in determining achievement levels in algebra and geometry. Schiefele and Csikszentmihalyi (1995) reported that *prior achievement* is strongly related to the level of the pupils' mathematical ability. Prior achievement in mathematics was also a predictor of pupils' mathematics achievement and in fact Tartre and Fennema (1995) found it to be the most significant predictor of future mathematics performance in their study of American pupils' progress from grade 6, 8, 10 and 12. Apart from cognitive ability, the pupils' *reading ability* has also found to be linked to pupils' mathematics achievement (Brookhart, 1997).

The issue of *gender* is commonly perceived to be a problem concerning pupils' achievement in mathematics. The perceived under-achievement and lack of participation of girls in these subjects at higher educational levels is generally a cause for concern. In his comparison of pupils in Australia and Ethiopia, Afrassa (1998) found that gender had an indirect effect on maths achievement over time. In both countries, boys performed better in mathematics than the girls. In another study involving pupils from Africa, Monyana (1996) found that the South African male pupils achieved higher scores but that the difference between the genders was not statistically significant (Monyana, 1996). No significant difference was found in the TIMSS 1995 study between the scores of boys and girls in South Africa (Howie, 1997). However, what is interesting to observe is that in a study using HLM and including grades 4,8 and 12 in the USA, Arnold (1995) observed that *"within schools in grades 4 and 8, little or no average gender differences were found in math…" "….In contrast, in grade 12, females averaged 2.5 achievement points lower than males in math…*"(p. vii). One interesting finding in relation to gender differences and achievement was that by Tartre and Fennema (1997) who found that *affective variables* tended to be more predictive of the mathematics achievement for males than for females.

Although pupils' attitudes towards mathematics have been found to be important (Afrassa, 1998), at least two studies have found that pupils' attitudes towards teachers also influence their achievement in mathematics (Georgewill, 1990; Newman & Schwager, 1993). Afrassa (1998) found in his analysis of the Australian TIMSS 1995 data that attitude was one of the most influential factors influencing their achievement.

Homework and time on task

Homework is seen a contribution towards pupils' learning extending the curriculum beyond the classroom. Afrassa (1998) found that the amount of homework given to

Australian pupils correlated with their achievement in mathematics. Martin, Mullis, Gregory, et al. (2000) found that time spent daily on homework on language, science and mathematics was a significant predictor for 13 out of the 18 countries included in the study. However, in South Africa, Monyana (1996) found that pupils who received more homework (daily, 4x, 3x per week) did not perform significantly better than those with less (never, 1x, 2x per week).

In a cross-national study (Shen, 2001) poor *school attendance* and high levels of absenteeism have significant and negative effects on maths achievement. This was a confirmation of a study by Bradford (1995), who also reported that pupils who were frequently absent also attained lower scores in mathematics.

3.4.2 Factors on classroom level influencing achievement

The learning environment and the classroom culture can have a tremendous influence on the pupils' attitudes to mathematics (Chapin & Eastman, 1996) and in turn their achievement in the subject. External factors such as the arrangement of the furniture in the class, the availability of resources and the length of the mathematics period were found by Chapin to be influential. Bode (1993) in the analysis of data from 1319 US pupils from 79 classes in 61 schools concluded that there was no advantage to being in a class with either heterogeneous or homogeneous mathematics ability levels. It was found that when explanatory variables consisting of characteristics of the class, teacher and instructional program are included in the modelling of mathematics achievement, they have no effect. The base HLM model of Bode showed that the relationship between majority/minority status and effort and the outcomes are the same across classes (p.11). In another study investigating the practice of tracking of pupils (i.e. separating pupils according to their ability into different tracks) in the USA (Brewer, Rees & Argys, 1995), the authors felt that previous research had failed to take account of the fact that observable teacher characteristics and other educational inputs vary across tracks (e.g. lower track classes tended to be assigned to least qualified teachers). They also felt that since assignment to tracks is made at least in part on the basis of prior ability, any real attempt to measure the effect of tracking itself must disentangle the influence of tracking from the process of assignment. Brewer et al's study found that high-track classes receive more educational resources than the lower-class tracks and that tracking was an important determinant of student achievement.

According to Arnold (1995, p. vii) several classroom instructional methods were associated with achievement. For instance, the more time spent in doing problems from textbooks, the higher the achievement of pupils in grade 4 and 8. Generally, the use of teaching aids was found to have a positive relationship to achievement by Mullis (1991). Working with objects (rulers, blocks, shapes and solids) was positively associated with geometry achievement in grade 4. However, using computers in maths in grade 8 was negatively associated with maths achievement (see also Pelgrum & Plomp, in press). Nonetheless using calculators and writing maths proofs in mathematics classes were associated with higher mathematics achievement in grade 12.

The differential effects of instructional methods and the management of classroom time are illustrated by a study by Schaub and Baker (1991) who compared more than 200 mathematics classes in the USA as well as more than 200 in Japan. The study concluded that Japanese teachers organised their classes and their time in an optimal way, which allowed them to be less restricted by the level of their incoming pupils' knowledge and ability.

On classroom level there are several *teacher variables* that have been found to affect a pupil's achievement in mathematics. Studies regarding teachers' attitudes towards mathematics (Chapin & Eastman, 1996; Dungan & Thurlow, 1989; Tooke, 1993) showed positive links to achievement as does a study about mathematics teachers' beliefs about mathematics (Chapin, 1996). A positive relationship was found between teachers' attitudes/expectations towards the pupils and their performance (Cheung, 1988; Sayers, 1994). However, also related to expectations was teachers differentiated behaviour towards boys and girls (Hensel, 1989; Randal, 1990) resulting in a negative link to achievement and stereotyping, namely that boys are good at mathematics and girls are not.

The effect of teachers' *competence* has been widely written about (Bloom, 1974; Bracey, 1991; Chen, Clark & Schaffer, 1988; Georgewill, 1990; Lockheed & Komenan, 1989; Taylor & Vinjevold, 1999; Tooke, 1993) and a positive link to achievement has been found in many studies. Some of the studies focused on specific aspects of competence sometimes producing contradictory results. Firstly, on the issue of experience researchers concluded that more experience generally resulted in better results (Chen et al., 1988; Lockheed & Komenan, 1989; Mullis, 1991). Teachers' confidence was an important factor and Bradford (1995) found that the teachers' confidence in being prepared for their lessons was essential and had a positive effect on pupils' achievement. The issue related to teachers' own education background was not as straightforward and produced some mixed, inconclusive and contradictory results when it was related to achievement (Maqsud

& Khalique, 1991; Mullis, 1991). However, most of the literature revealed that there is evidence that the teachers' education matters. For instance, several researchers found that there was a difference in achievement where teachers are well qualified or not (Bracey, 1991; Lockheed & Komenan, 1989; Mullis, 1991; Tooke, 1993). Bradford (1995) found that the teachers' major subject mattered and that if the teacher had a major in mathematics then the pupils' achieved higher test scores in mathematics. He also found that teachers' familiarity with, and knowledge of, the content and the didactics influenced the learning environment of the classroom significantly. A study by Mandeville and Liu Qiduan (1997) provides evidence that the amount of teacher preparation (training) has an effect on the structure of pupils' learning. Seventh grade pupils tended to perform better on higher level thinking tasks when the teachers teaching them had advanced certification in mathematics. Mullis (1991) found that more in-service training in most states in USA led to better results of grade 8.

In South Africa the issue of teacher qualifications is politicised and is a really difficult education issue as about 50% of the mathematics teachers have no formal qualification in mathematics (Arnott & Kubeka, 1997). Mpofana's study (1989) in KwaZulu-Natal revealed that in an area where the matriculation (final year of schooling's national examinations) results were low in mathematics, the teachers were not well qualified, had no extensive experience teaching mathematics and had to teach two or three other subjects as well in addition to mathematics. This is perhaps explained by Meyinsse and Tashakkori (1994), who found that pupils' performance also suffered if they perceived teachers' teaching to be poor and if they thought that teachers were indifferent to their teaching.

Amid the mass of literature indicating differently, a study in South Africa (Monyana, 1996) found no significant difference in the results between teachers with higher qualifications or those with lower qualifications. Nor did he find any difference between those that had more INSET than those had less. The reason for this is not obvious from the information that is available.

Teachers' methods using small group work also produced contradictory results. Whilst a positive link to achievement was found by Abrami, Chambers, D'Appollonia and Farrel (1992), negative links were found by Schaub and Baker (1991). This may be due to the type of children that were investigated. It is often the case that children requiring remedial assistance work with the teachers in small groups.

Cohn and Ressmiller (1987) did not find that class size was consistently related to achievement. So despite many European classrooms having smaller groups than many countries, the Pacific Rim countries often have large classes (more than 40 on average). However, in recent study by Martin, Mullis, Gregory, et al. (2000), class size was a significant predictor for eight of 18 countries studied in addition to its importance for other educational goals.

Time on task, i.e. the number of hours of instruction in a subject and the number of hours of homework given by the teacher are important (Bloom, 1974). Generally, the amount of homework given by teacher was found to have contradictory effects on mathematics achievement. Whilst Mullis (1991) found that the more homework pupils were given, the lower results they achieved in mathematics, Mudeliar, (1987) and Sedlacek (1990) found the opposite, namely the more homework pupils were given, the higher results their results were in mathematics. Bradford (1995) found that assigning one-hour of homework a day and discussing the homework afterwards had a positive effect on the pupils' achievement. This is supported by Meyinsse and Tashakkori (1995) who found in their study of 9 000 American pupils that time spent on homework assignments in general had a positive relationship to achievement. Whilst pupils' time on homework was found to be significantly and positively related (Chen et al., 1988; Sedlacek, 1990), no correlation was found by Wong (1992). However, Bradford (1995) did find that failing to complete homework had a negative effect on mathematics achievement.

Besides homework, a number of different classroom-level factors were found to be related to achievement. Inattentiveness in class and disruptions in class had a negative impact on achievement (Bradford, 1995). Calculator use by pupils was significantly and positively related (Munger and Lloyd, 1989; Mullis, 1991; Siskind, 1994) to achievement in mathematics. Also positively related was the content coverage (Chen et al, 1988; Hafner, 1993; Lockheed, 1990; Raphael, Wahlstrom & Mclean, 1989).

Studies investigating the *frequency of assessment* found a positive relationship to mathematics performance. Achievement improves as the rate of testing increases (Dineen, Taylor & Stephens 1989; Kika et al., 1992; Ma, 1995). In contrast, Monyana (1996) found that those pupils who wrote fewer tests (not more than once in a term) achieved better results than those who wrote tests more frequently.

The *personality* of the teacher and personal relationship with the pupils was positively linked to achievement. Generally, pupils who liked their teachers performed better in maths (Dungan & Thurlow, 1989; Meyinsse & Tashakkori, 1994; Mudeliar, 1987). A positive relationship was found between the pupils' ability to talk to their teachers and their performance in standardised mathematics tests. Similarly, earlier it was said that Georgewill (1990) had found that pupils' attitude towards their teachers to be positively influential.

Although the gender of the teacher was not found widely reported, Monyana (1996, p. 143) in South Africa found that teachers' gender was not a factor in pupils' results. In that study, pupils with female teachers achieved better results at maths although the results were not significantly different.

3.4.3 Factors on school level influencing achievement

Research focusing on schools has been underway for more than 30 years. During this time, research has assumed a number of mantles namely school effectiveness, school improvement, school reform, school development, and school restructuring amongst others. Through this research a number of factors related to achievement have been uncovered at different levels in the education system, i.e. at school-, class- and student-level. Many authors attribute the start of this type of research to the team under Coleman in 1966 (see Coleman et al., 1966) who found that home background in the United States of America predicted by far the greatest variance in achievement outcomes. Using multiple regression analysis, Coleman et al. reported that poverty and class were responsible for predicting achievement more reliably than school factors. School-level factors have traditionally explained a low percentage of variance in many research projects primarily conducted in developed contexts. Reynolds and Cuttance (1992) reviewed a number of studies and found only 8-15% of variance attributable to school factors. Most of the research done so far has been in the developed nations and largely in Western Europe and the United States of America (see Gray et al., 1999; Mortimore, 1998; Sammons, 1999; Teddlie & Reynolds, 2000; amongst others).

A number of studies also investigated the effectiveness of schools. New techniques were developed to do this. Edmond's 5-factor model (1979) was developed through a longitudinal study and Rutter, Maughan, Mortimore and Ouston (1979) and Mortimore (1998) used complex data and multilevel analysis techniques for the first time.

A variety of factors have been found that influence achievement (see Creemers, Reynolds, Stringfield et al, 2002). Specifically, it has been reported, in a review by Greenwald, Hedges and Laine (1996) that a number of studies found class size to have a minor effect on achievement. Fuller and Clarke (1994) identified three factors – *textbooks*, *teacher quality* and *time* as being key factors emerging from school effectiveness research. These are also mentioned by Riddell (1997) and in a review by Creemers (1996). *Leadership, organisation and management* are identified as important factors by school effectiveness researchers, whilst school improvement researchers have concentrated on *decision-making, within-school hierarchy* and *communication*.

In the past few years, calls have been made to link school interventions and contextual information with pupil achievement data. West and Hopkins (1996), stated that a school improvement strategy needs to be based on data about pupil performance claiming that different achievement profiles require different kinds of intervention.

There is a significant difference between the variance in achievement explained at different education levels between and within-countries. Reynolds (1998, p. 1279) claims that classroom-level has "*maybe two or three times the influence on student achievement than the school level does*". Scheerens (1998) conducted an extensive review of the literature on school effectiveness and the synthesis of the research outcomes revealed support for Reynolds earlier conclusion, namely that factors at classroom level correlate generally more highly with achievement than those at school level.

In another review of literature at school level Muller and Roberts (2000, p. 17) concludes that home background is more influential than school "*because most of the damage is done before the children go to school*". However, the complexity and peculiarities of schools is maybe magnified by highly disadvantaged settings such as those in South Africa and other developing countries. There is a need to explore and disentangle the multiple associations and divergent outcomes derived from the same set of input variables. Multi-level modelling may be seen as an aid to do this, hence the growing tendency by researchers to use this technique. It is clear that although researchers may be approaching data from different perspectives (i.e. school improvement or school effectiveness), there is considerable interest in ascertaining the reasons related to the successful learning of pupils in schools across the world. Seemingly instructional factors at classroom level are more important than factors at school-level. In the developed world, researchers maintain that home background factors predict achievement of children in those countries.

The research suggests that many of the school effects on achievement are indirect and may perhaps have less of an influence than the class or student level. The advent of multilevel allows the researcher to ascertain the extent of the influence of one level compared to another. In the study by Young (1997) the application of multilevel modelling to the Australian data revealed that the difference in scores was mostly explained on student level (between students).

In general those schools that are effective across countries in the Pacific Rim (Teddlie & Reynolds, 2000, pp. 250-252) in terms of their pupils' overall performance are those with (amongst others):

- A strong commitment to academic goals;
- A controlled environment exhibiting cohesion, consistency, constancy and stability;
- A strong pro-active kind of schooling;
- Effective management of time, with high time on task and the transitions between lessons and between lessons and break times being well organised;
- Good teacher/teacher relationships between professionals whose curriculum knowledge is excellent;
- Highly interactive classroom teaching with a balance of control/autonomy.

In the USA, schools that were most effective in terms of their mathematics achievement (Mullis, 1991, pp. 77-82) had pupils that watched less television, changed schools less often, were subject to only a moderate amount of testing in their mathematics classes, took more advanced courses, had positive attitudes towards their subjects, had fewer problems in the schools (although Vari (1997) found for Hungary no relationship between problems in the school and pupils' achievement), and did mathematics and used calculators more frequently.

Cohn and Ressmiller (1987) concluded that leadership of schools, composition of pupil body, academic emphasis, use of time in school, and professional development of staff were important variables related to achievement.

Teachers in large schools reported more reasons for the lack of pupils' progress in mathematics than in smaller schools (Raphael, Wahlstrom & Mclean (1989). The schools' locality is related to achievement (Young, 1997) and pupils in rural areas achieved lower scores. School resources are not generally associated with achievement as Arnold (1995, p. vii) found in her study of NAEP data using HLM across three grade levels in the USA. This was also confirmed by Vari (1997) reporting on a national study in Hungary who found that school equipment had no effect on Hungarian pupils' achievement.

3.4.4 The difference between factors influencing achievement in developed and developing countries

There is evidence as shown in (3.4.1-3.4.3) that a number of variables do affect pupil achievement. These include the leadership of the school, composition of the pupil body, the academic emphasis within the school and classroom, classroom management and discipline, the use of time in school, the home environment of the pupils and the professional development of the schools staff. The determinants of school achievement in developing countries differ from those in developed countries (see Heyneman, 1976; Heyneman, 1986 and Heyneman & Loxley, 1983) and it has been suggested by Cohn and Ressmiller (1987) that as a society becomes more industrialised, school achievement is likely to be influenced more strongly by the pupils' socio-economic background and other extramural factors. The authors considered some of the distinct differences between developed countries and developing countries. These included expenditures on education in developing countries, which are a small fraction of those in the Western Countries as well as the difference in the cultural factors. Studies in developing countries generally confirm results cited earlier for developed countries concerning the effect on achievement of factors such as good classroom management, time on-task in reading, homework and the hours of instruction. Textbooks, teacher motivation and homework appear to have a significant effect on achievement in developing countries. The growing evidence on school effectiveness in developing countries suggests that school resources do indeed matter. Class size is not consistently related to pupil performance, and researchers do not find a consistent relation between budgetary outlays and achievement. Nevertheless, school resources appear to exert a significant effect on achievement, indicating that wise use of resources in developing countries are expected to promote educational improvement. The World Bank (1995) has in particular revealed this through their studies. However, effective school research also serves to underline the importance of pedagogical skills in developed countries. Skills in classroom management as reflected in maximizing the time devoted to academic instruction, maintaining order and discipline, establishing clear goals and objectives and so on was a distinguishing characteristic of effective schools. Time in-school and out-of-school learning may be extremely important. Nonetheless the more recent findings in school effectiveness studies show that school-level factors influence achievement far less than do factors at the class-level. However, as this research is largely based in developed countries, the question remains whether this is also the case in less-developed nations.

The situation in developed and developing countries may well be different in relation to outcomes in research on school level and which factors influence pupil achievement. One important difference is that resources at schools are more important in developing countries. The World Bank (1995) lists libraries, time on task, homework, textbook provision, teacher knowledge, teacher experience, laboratories, teacher salaries and class size as important for effective schooling in developing countries. Other influential factors found are teacher expertise and competence, strong leadership, clear organisation of the school day and the learning programme (time and opportunity) and community and parental involvement in school governance (Muller & Roberts, 2000, p. 8). In South Africa, an investigation into well performing schools by Crouch and Mabogoane, (1998) found that only 25% of achievement was explainable by resource availability. The variation in findings illustrates the importance of the context of the research.

Afrassa (1998) compared the mathematics results of Australian and Ethiopian pupils using the TIMSS 1995 study and found that the Ethiopian pupils achieved lower results. His analysis revealed that Ethiopian pupils had less opportunity to learn similar items than their Australian counterparts. The Ethiopian government spent less money on their pupils than the Australians did. The class sizes in general were much greater for the Ethiopians. In the analysis of factors influencing achievement, there were four common factors found that directly influenced the achievement of both the Ethiopian and the Australian pupils. These were *home background, class size, time on learning* and *attitude*. The additional factors that influenced the Ethiopian pupils' achievement exclusively were *gender* (with boys achieving higher scores) and *age* (younger pupils performing better than older pupils in the same class). The additional influential factor for the Australian pupils' achievement was their *views about mathematics.*

3.5 SUMMARY

A number of different issues linked to pupils' achievement were covered in this chapter. Whilst there are many studies touching on or including assessment of mathematics achievement, these have tended to be smaller scale and less comprehensive than this study, at least in South Africa. Internationally, research addressing factors related to achievement were found using data from Australia, Belgium, Ethiopia, Indonesia, Eastern Europe and the Netherlands, but most were found in the USA. However, none were found in South Africa using a nationally representative sample. No studies were found either nationally or internationally that attempt to link English Language proficiency to mathematics achievement using such a comprehensive dataset with data on pupil, class and school levels.

It is clear that SA pupils are performing poorly nationally and that there are fewer pupils than desired that take national examination at university entrance level. The introduction of national assessments recently mean that South Africa will have additional means of measuring the performance of the system. No other national studies have been conducted regarding mathematics achievement. South Africa has participated in a number of international studies namely, TIMSS, TIMSS-R, MLA and most recently SACMEQ. These have filled the void of information in the areas of mathematics, science and language and national achievement. In all studies (with the exception of SACMEQ whose data is not yet available) the performance of South African pupils has been comparatively poor.

Studies regarding the effects of language on mathematics achievement (see section 3.3) were reviewed and appear to indicate the importance of language in achievement generally including mathematics. There seems to be sufficient evidence internationally and some evidence locally to warrant the assessment of language and its relationship to mathematics on a large scale in South Africa.

Finally the chapter-covered factors related to achievement on the pupil-level (see section 3.4.1), class-level (see section 3.4.2) and school-level (see section 3.4.3) and some of the differences between influencing developed and developing countries were discussed in 3.4.4. Some of the differences between factors influencing achievement in developed and developing countries were discussed briefly in 3.4.4.

Overall, a multitude of literature was found with the size of the studies varying greatly from case studies to large-scale surveys. Clearly there are many factors that have been found on all three levels to have positive and negative effects on mathematics achievement. Those factors discussed on *pupil level* included: socio-economic status, books in the home, parental education, parents occupation, parental relationships, parental press, parent's self-concept, pupils' attitudes to mathematics, family size, jobs in the home, pupils' aspirations, peer group attitudes, pupils' self concept, self expectations, pupils' anxiety, enjoyment of mathematics, attitudes towards maths, cognitive ability, reading ability, gender, age, attitudes towards teachers, time spent on homework. Of these most will be investigated in the TIMSS data in this study. The exceptions are parents' occupations, parental relationships, parents' self-concept, pupil anxiety, cognitive ability, reading ability and attitudes to teachers. This is not because they are not important, but rather due to the limitations of the dataset to be used.

On classroom level, factors found in the literature were the learning environment, teacher's characteristics (including gender), teacher's personality, streaming, instructional methods, computers, teachers' competence, teacher's confidence, education background, teacher's qualifications, teachers' methods, class size, time on task, disruptions in class, calculators, content coverage, and assessment. Of these most will be explored in the study, the only exceptions being teacher's personality and content coverage. The former, not having been included in the questionnaires and the latter due to data problems where the data could not be recovered.

Finally on school-level a number of factors have been investigated in previous studies. These included textbooks, teacher quality, time on task, leadership, organisation, management, decision-making, within-school hierarchy, communication, school size, professional development, location, commitment, and the controlled environment. In this study, only textbooks, time on task, leadership, decision-making, school size and location can be explored, as the other factors were not included in the data collection.

In chapter 5, a framework is given for exploring the above factors and their inter-relationships. Details of the TIMSS-R study from whence the data were derived, is discussed in the following chapter (chapter 4) and provides the necessary background for the design of the study in Chapter 5.

CHAPTER 4
TIMSS-R in South Africa

In this chapter a number of design issues of TIMSS and TIMSS-R are highlighted that are important for this research. The conceptual framework, research questions, sample, instrument development, data collection and data processing are described and discussed in this chapter. The conceptual framework followed the traditional IEA conceptual frameworks using intended, implemented and achievement curricula. Internationally designed achievement tests in mathematics and science using a rotation design were administered to more than 9 000 Grade 8 South African pupils. Questionnaires were given to the pupils, their mathematics and science teachers and principals of schools. Achievement tests contained multiple-choice and free-response items, the latter required scoring using a two-digit scheme designed especially for TIMSS.

This chapter focuses on design issues related to TIMSS and TIMSS-R that are important for this study. Firstly, the conceptual framework and the research questions are presented in 4.1. In 4.2, the South African sample for TIMSS-R is described. The instrument design and development, which includes the questionnaires and achievement instruments, is discussed in section 4.3. In 4.4 the data collection methods and procedures are described followed by the data processing in 4.5. For additional information consult Martin and Kelly (1996) and Martin, Gregory and Stemler (2000) for more details of the research design of the TIMSS and TIMSS-R international study and to Howie (2001) for more specific information about the South African design and study.

4.1 CONCEPTUAL FRAME AND RESEARCH QUESTIONS OF TIMSS AND TIMSS-R

The IEA's Third International Mathematics and Science Study (TIMSS) was conducted in 1994 and 1995 (see Beaton, Martin, et al., 1996, Beaton, Mullis, et al.,

1996) and a replication study (TIMSS-Repeat, or TIMSS-R) [1] followed in 1998 (see Martin, Mullis, Gonzalez, et al., 2000); Mullis et al., 2000). There were several types of data collected through mathematics and science tests, questionnaires, performance assessment tests and a curriculum analysis project.

Three populations were tested in TIMSS and only one in TIMSS-R (Population 2). These are described as populations 1, 2 and 3. Population 1 comprises the students[2] in the pair of adjacent grades that contained the most students who were 9-year-olds at the time of testing. Population 2 consists of students in the pair of adjacent grades containing the most students who were 13-years old at the time of testing. Finally, population 3 includes students in the last year of secondary school, regardless of the type of programme in which they were enrolled (Robitaille & Garden, 1996). Mathematics and science curriculum-driven achievement tests were administered to students in Population 1 and Population 2 (and those students in Population 3 who specialised in mathematics and/or science), whilst mathematics and science literacy tests were administered to students in Population 3. The TIMSS design required that a minimum of 150 randomly selected schools be sampled per population group. All participating TIMSS countries were required to participate in Population 2 with Populations 1 and 3 being optional. South Africa participated in TIMSS for Population 2 and the literacy part of Population 3; the results are reported in Howie (1997) and Howie and Hughes (1998).

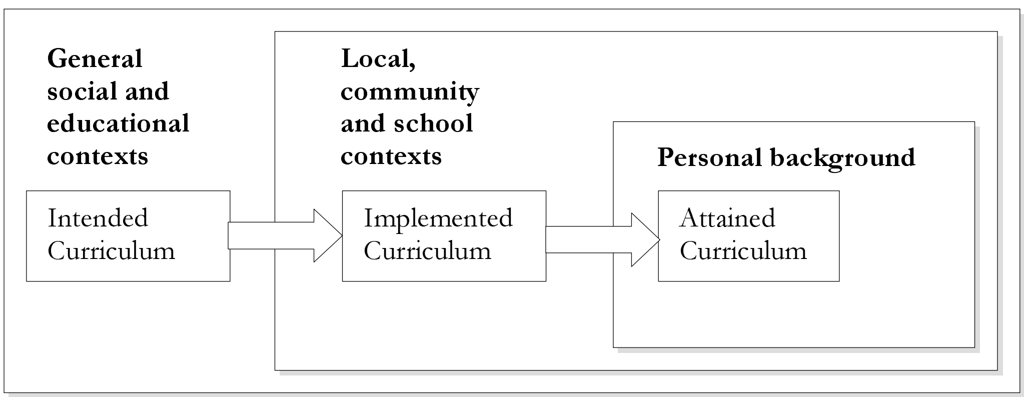
The conceptual framework for TIMSS was derived from previous studies conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). IEA studies traditionally have recognised the importance of the curriculum as a variable for explaining differences among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

[1] As TIMSS-R is a repeat of TIMSS for one population, both studies have the same design. Therefore, in this chapter TIMSS and TIMSS-R are used interchangeably.

[2] The TIMSS studies use the term 'student' and therefore student and pupil are used interchangeably from here onwards.

The conceptual model for TIMSS was derived mainly from the models used in earlier IEA studies, especially for SIMS (Second International Mathematics Study; Travers & Westbury, 1989) and SISS (Second International Science Study). In this model three "levels" of curriculum are envisaged (see Figure 4.1): the intended, the implemented and the attained curriculum. The intended curriculum is perceived as society's goals for teaching and learning; the implemented curriculum refers to what teachers actually teach and what is going on in the classroom, while the attained curriculum consists of what students actually learn and their attitudes towards what they have learnt.

The educational environment, made up of a variety of factors, should be understood from the perspective of these three curriculum levels. It is believed that there are factors outside formal schooling that affect the student's achievement. There is a unique set of contextual factors that influence the educational decisions for each level of the curriculum (Martin & Kelly, 1996).



Source: Robitaille et al., 1993.

Figure 4.1
TIMSS Conceptual Framework

Four general research questions address the main components of TIMSS (and TIMSS-R), being the three curriculum levels and the relationships between them:

1. *Intended curriculum*: What are mathematics and science students around the world expected to learn? How do countries vary in their intended goals and what characteristics of education systems, schools and students influence the development of these goals?
2. *Implemented curriculum*: What opportunities are provided for students to learn mathematics and science? How do instructional practices in mathematics and science vary amongst countries, and what factors influence these variations?

3. *Attained curriculum*: What mathematics and science concepts, processes and attitudes have students learned? What factors are linked to students' opportunity to learn, and how do these factors influence students' achievement?
4. How are the intended, implemented, and attained curricula related with respect to the contexts of education, the arrangements for teaching and learning, and the outcomes of the educational process?

4.2 SOUTH AFRICAN SAMPLE FOR TIMSS-R

South Africa's sampling frame for TIMSS-R included 7,234 schools with 968,857 pupils. In the first sampling phase, 225 schools were selected from all 9 provinces (the explicit strata). Additional implicit strata included the language of instruction (English and Afrikaans) and school funding (state, state-aided and private). Equal sample allocation was done by the explicit strata to produce estimates per province. Special explicit strata was also done in the Gauteng province to produce the schools required for the field trial conducted in English schools only. The national database of schools compiled by the HSRC for the National Department of Education in 1996 was used.

Within-school sampling procedures

For the second phase of sampling, information regarding the number of Grade 8 mathematics classes and pupils for the selected schools was collected. Thereafter the procedures for randomly selecting whole classes were performed according to the TIMSS-R guidelines resulting in one intact mathematics class per school being selected.

In South Africa, mathematics and general science are compulsory subjects up to the end of Grade 9 and therefore most schools are expected to provide tuition in these subjects. There are exceptions, but these are in the minority. Therefore in most cases, principals simply supplied the Grade 8 class information or lists as pupils are taught mathematics within their normal classes. In very few cases streaming occurs and this happens primarily in private schools of which there were very few in the sample. Generally, mathematics and science teachers are assigned to a class, which is not tracked or streamed specifically for those subjects. In cases where tracking occurs, this is generally according to the pupils' overall ability or results and not specifically for mathematics ability or science ability. No exclusions were made as per the guidelines from the International Study Centre.

4.3 INSTRUMENT DEVELOPMENT

The TIMSS and TIMSS-R research was conducted at three levels: the curriculum analysis level, the achievement tests level and the questionnaires level. The instruments used in TIMSS-R were in principle the same as the ones used for Population 2 in TIMSS. First the questionnaires are discussed in 4.3.1, followed by the achievement instruments (4.3.2). Finally the test design is elaborated in 4.3.3.

4.3.1 Questionnaire design and development

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

The questionnaires used for TIMSS and similarly for TIMSS-R were based on a review of the school, teacher and student factors shown in previous research to be related to pupil achievement. Questionnaires were developed for the school principal, the mathematics teacher, the science teacher and the pupil. The contents of the questionnaires are contained in appendix 1.

A **school questionnaire** was designed for the principal of each sampled school. The results from these questionnaires should give a good idea of the kinds of schools in the education system. Among the topics addressed in this questionnaire were enrolment, demographics and subject selection, as well as administrative, curricular, budgetary and social issues.

There were two **teacher questionnaires** to obtain information on the curricula implemented at school; one of which was designed for the mathematics teachers and one for the science teachers. The questionnaires included five topics: the teacher's background, attitudes to teaching and learning, expectations for pupils, instructional practices, and opinions on mathematics and science education.

The questionnaire for **pupils** included questions on the pupil's background, opinions and attitudes to mathematics and science.

4.3.2 Achievement instruments

Traditionally, large-scale surveys conducted by the IEA and other bodies have used multiple-choice questions. Tests using the multiple-choice format are very popular since the test conditions can be standardised, the cost is low and they can be machine-scored. However, there has recently been a growing awareness among educators that some important achievement outcomes are either difficult or impossible to measure using the multiple-choice format. Communicating mathematical or scientific findings or constructing a mathematical proof requires skills for which the multiple-choice questions appear to be unsuitable. It was therefore decided that TIMSS (and therefore TIMSS-R) should employ a variety of questions to increase the coverage of the desired outcomes of school mathematics and science education. Four different types of questions were included in the pool of TIMSS questions: multiple-choice questions, short answer questions, extended answer questions and performance tasks (not included in TIMSS-R). (In TIMSS the short answer and the extended answer questions were referred together as free-response items). As in all other countries, these achievement tests were written in the pupils' language of instruction, which for South African pupils was English or Afrikaans.

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

In both the short answer and the extended response questions, pupils were required to write their responses and these were coded. For the short answer items, the pupils were required to write a brief verbal or numerical answer. The multiple-choice, short answer questions and extended response questions were randomly distributed, in different groups or clusters of questions, throughout the test booklets.

4.3.3 Test design

TIMSS used a rotation-design in which for instance in population 2, the items were grouped into 26 clusters each containing 10-18 items each. All the clusters were rotated through the eight test booklets. Some items appeared in all eight books and others in half or only one book. The books were designed to be of equal difficulty and length and were answered in 90 minutes. Every pupil tested completed one test book, which was randomly distributed, as well as one questionnaire (Robitaille & Garden, 1996, pp. 89-97).

The mathematics and science tests were developed internationally in a collaborative manner. Pilot and field trials of the items were carried out and translated versions were stringently reviewed. The items comprised multiple-choice questions, short-answer and extended answer questions. The free response questions required coding and coding guides had to be developed for this purpose. TIMSS developed a two-digit coding scheme to diagnose pupils' answers to the open-ended questions. For instance the first digit registered the degree of correctness, whilst the second digit was used to code the type of correct or incorrect answer given. The items were coded correct or incorrect, and the pupils were not required to show details of the approach they used or the calculations they performed on such questions (Martin & Kelly, 1996, p. 7-7). The ultimate aim of this scheme was to provide a rich database for research on pupil's cognitive processes, problem-solving strategies and common misconceptions (Robitaille & Garden, 1996, pp. 69-71).

4.4 Data Collection

Co-operation from schools

The co-operation from relevant authorities and the schools in general was excellent. Firstly, the permission to contact the schools was sought from the provincial education departments and this was obtained from 7 of the 9 provinces. In the case of the non-responding provinces, all efforts were made to contact the Director-General of these provinces, but with no success. Nevertheless, the schools from these two provinces were still contacted directly by the National Research Centre for TIMSS-R and were included in the study. In general the National Centre sent a letter signed by the President of the HSRC to all the selected schools. Where possible the schools were contacted telephonically to follow up the letters to explain the nature of the study and the procedures. For schools without telephones, they were visited on-site to follow up the letter (and in some cases to provide a copy where letters had not arrived) and secure dates for testing. A Market Research Company was contracted by the HSRC to perform the fieldwork as schools could not be relied on and postage of materials was judged too risky. These field-workers in all cases visited the schools prior to the testing to ensure the co-operation of the schools.

Problems with obtaining co-operation

In total 7 schools across 4 provinces (3 in Gauteng, 1 in Kwazulu-Natal, 2 in North West Province and 1 in Northern Province) refused to allow their pupils to be tested. The primary reason given was the poor timing of the testing, which clashed with the year-end examinations. This was of great concern to all the schools in this study and this impacted heavily on the time it took to get participation. It impacted as well on the attendance figures as pupils simply did not turn up for school (and the testing). The feedback from the schools indicates that they would prefer testing to take place after the mid-year break.

Another general problem was that schools could not be found or contacted. In total, 19 schools in 6 provinces could not be contacted, necessitating the use of replacement schools. The reasons for this include the fact that some of the school names have changed since 1994 and therefore were unknown, inadequate postal services, and the fact that most schools do not have telephones.

Finally, despite all efforts to use up to date lists of schools, some of the schools had changed structurally and some cases in having become primary schools (Grade 1 – Grade 7) and therefore no longer having Grade 8 classes.

Testing sessions

The field-workers in consultation with an allocated staff member (often the school principals) organised the testing sessions. This was done in keeping with the TIMSS-R guidelines. One intact class was tested and the test booklets were randomly distributed according to the pre-allocated system. Pupils writing the same booklets were evenly distributed throughout the class to prevent cheating. The majority of the sessions took place at the start of the school day.

Test Administrators

The HSRC contracted a field agency to administer the test. Thus, field-workers were subcontracted by this field agency but were trained by the National Centre staff (mainly the NRC). The training for these field-workers took place in each main centre in South Africa – two sessions were conducted in Johannesburg, one in Cape

Town, one in Port Elizabeth and one in Durban. These sessions lasted approximately 6-8 hours on one day. Topics covered included background information about TIMSS; the test instruments; the survey activities forms; test administration procedures; and quality control issues. The adapted Test Administrators manual was also explained in detail. Finally, a couple of hours were allocated for discussing how to cope with different scenarios and potential problems.

The school co-ordinator was usually the principal or the delegated person who organised the venue and time for testing, and in some cases assisted the field-worker to organise the pupils. Due to the reduced nature of the school co-ordinators' role there was no training involved and where possible further information was given telephonically.

Test Administration

Essentially, field-workers reported three main problems and these were experienced essentially in schools where African pupils were predominant:

- Difficulty with the language – pupils did not understand a number of words (for example, *internet*; *ozone layer*; *endangered species*; *disagree*, *immediately; situated; destruction*, amongst others). Many pupils struggled to complete the questionnaires and a significant amount of help was needed from the field-workers with these questions to understand the language.
- Tests were too difficult – many field-workers reported that pupils in predominantly African schools struggled with the test.
- Insufficient time to complete the tests – this was possibly linked to the previous two points, as pupils again in predominantly African schools had difficulty with the language and found the content of the tests difficult, and therefore took longer to read the questions as well as to answer them.

Apart from the problems experienced by the pupils, field-workers did not report any other general problems.

4.5 DATA PROCESSING

Coding of booklets

During December 1998, fifteen scorers were trained in the free response coding. These scorers were teachers and lecturers of mathematics, physical science, and biology. The full pool of scorers had to represent all population groups in the country as well as different language groups.

Prior to the coding of each booklet, coders underwent a half-day training session on the booklet. Coders then did the reliability coding on 25% of the booklets before coding the full set of booklets. The booklets were subsequently marked in sequential order. This meant that all of the booklet number ones were marked before booklet two, and so on.

The first phase of the coding was done over two weeks in December 1998 and coders were able to complete up to booklet 5. The second coding phase took place in late January 1999 where the coding of the remaining booklets was completed. The coding was split as it was anticipated that with the main holiday period over December /January, and the busy schedules of teachers at the beginning of the academic year, there would be some difficulty in completing the coding during the planned time period of February 1999.

In the interim period between the two coding phases, booklets 1-5 were quality checked. At least two batches of each coder were checked as well as the reliability coding. Where problems were detected, all the books of a particular coder were checked and altered accordingly. As a result of this process, the size of the coding group was reduced and only the best coders were invited to participate in the coding in phase 2. By mid February the coding had been completed including quality checks on all coders.

The data entry process went very smoothly and the background questionnaires were coded to make it easier for the data punchers. Although only a 5% verification was expected, a 100% double entry was done. Corrections were only done on the original file and not on the verification file, therefore there is still an error rate, but this is less than 1%. Data cleaning was extensive from both the National Research Centre and the IEA's Data Processing Centre and was completed over a period of six months.

CHAPTER 5
Research design and methods

The aim of this study is to describe and explore the main factors influencing the performance of the South African pupils in the mathematics test of the Third International Mathematics and Science Study-Repeat (TIMSS-R). Two conceptual models informed the conceptual framework of this study, namely the IEA's research study model (Travers & Westbury, 1989) and the Shavelson, McDonnell and Oakes's (1987) model about elements of the education system and the interrelationships between these elements. In the first phase of the study, the study seeks to describe the participants in the study and the performance of the pupils. In the second phase, the exploratory phase, the study investigates the factors that have an effect on student, classroom and school level.

In this chapter, the issues related specifically to the design of the study are described and discussed. Firstly, the problem is given in its context closely followed by the conceptual framework (5.1) and research questions (5.2). Thereafter some design issues related to the sample, data sources, and procedures followed are discussed and the analysis plan is summarised (5.3).

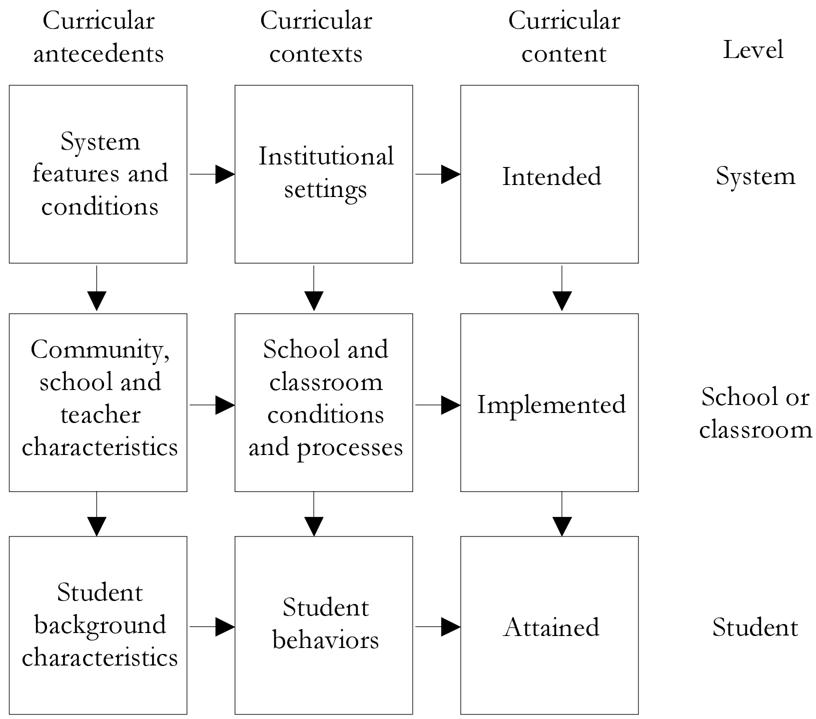
5.1 CONCEPTUAL FRAMEWORK

The aim of this study is to describe and to explore the main factors influencing the performance of the South African pupils in the mathematics test of the Third International Mathematics and Science Study-Repeat (TIMSS-R). The first phase's objective is to describe the performance of the pupils in the mathematics test, pupils' proficiency in English as well describing the background characteristics of pupils, teachers and schools to the extent measured by TIMSS-R. The objective of the second phase is to explore the factors (and their inter-relationships) relating to the pupils' performance and language proficiency in relation to the background information that was collected from the pupils, teachers and principals of the schools included in the study.

As argued in chapter 1 (1.1) and chapter 2 the issue around the language policy for teaching and learning has become a sensitive and controversial topic in South Africa. Therefore as part of the ongoing debate of language in the country, it is important to ascertain the relationship between the pupils' proficiency in the language of learning and their performance in mathematics and to try and identify any other significant factors influencing pupils' achievement in mathematics.

In order to address these objectives of the study, it is clear that the conceptual framework for this research must allow for developing research questions that explore factors within different levels influencing pupils' achievement in mathematics within the context of South Africa described above.

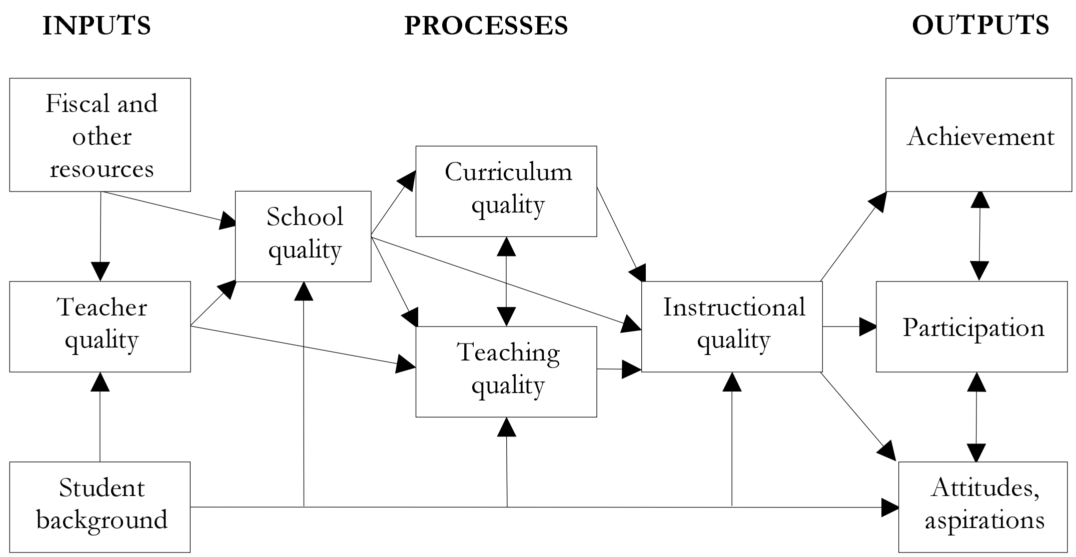
Two models were influential in informing the conceptual model for this research. The first is the one that underpins the TIMSS data being analysed in this study, namely the IEA model. Over the past 40 years the IEA have applied large-scale research methods through (with a few exceptions) a curriculum-based, explanatory design that have varied in form and content across studies (Plomp, Howie & McGaw (in press)). The generic IEA conceptual framework is summarised in Figure 5.1. Here the curricula are examined at the system-level (intended curricula), school/classroom level (implemented curricula) and on the individual student-level (attained curricula). Curricular antecedents (such as background characteristics and school and home resources) can be investigated in relation to curricular contexts to predict curricular content outcomes. A number of studies have shown that factors on a number of levels influence pupil performance at school (Keeves, 1994; Pelgrum & Plomp, 1991; amongst others).



Source: Travers and Westbury, 1989; IEA guidebook, 1998; p. 33.

Figure 5.1
Model of an IEA Research Study

The second model is that derived by Shavelson, McDonnell and Oakes (1987); see Figure 5.2. To monitor a dynamic system such as education, it is important to depict this in a way that linkages between components of the system can be ascertained and evaluated. Shavelson et al. (1987) did a comprehensive review of the literature relating to social indicators and educational research and developed a model that would illustrate these linkages. Whilst Shavelson et al. originally constructed the model as a framework reflecting merely the linkages of the different elements of the education system and not to indicate causality, they reported that there were correlational analyses that supported these links.



Source: Shavelson, McDonnell & Oakes, 1987.

Figure 5.2
Linking elements of the educational system

To identify and depict possible relationships between the elements of the education system, a number of elements have been added to and adapted in Shavelsons' original model (see Figure 5.3). The component of *national, provincial, local contexts and education policies and system* (to reflect the structure of the SA education system and context), the component of *pupil's aptitude, attributes and competencies* (to reflect pupils' prior knowledge and skills) and the three levels of the curriculum: *intended*, *implemented* and *attained* (to reflect the IEA conceptual thinking) are all additions to Shavelson's model.

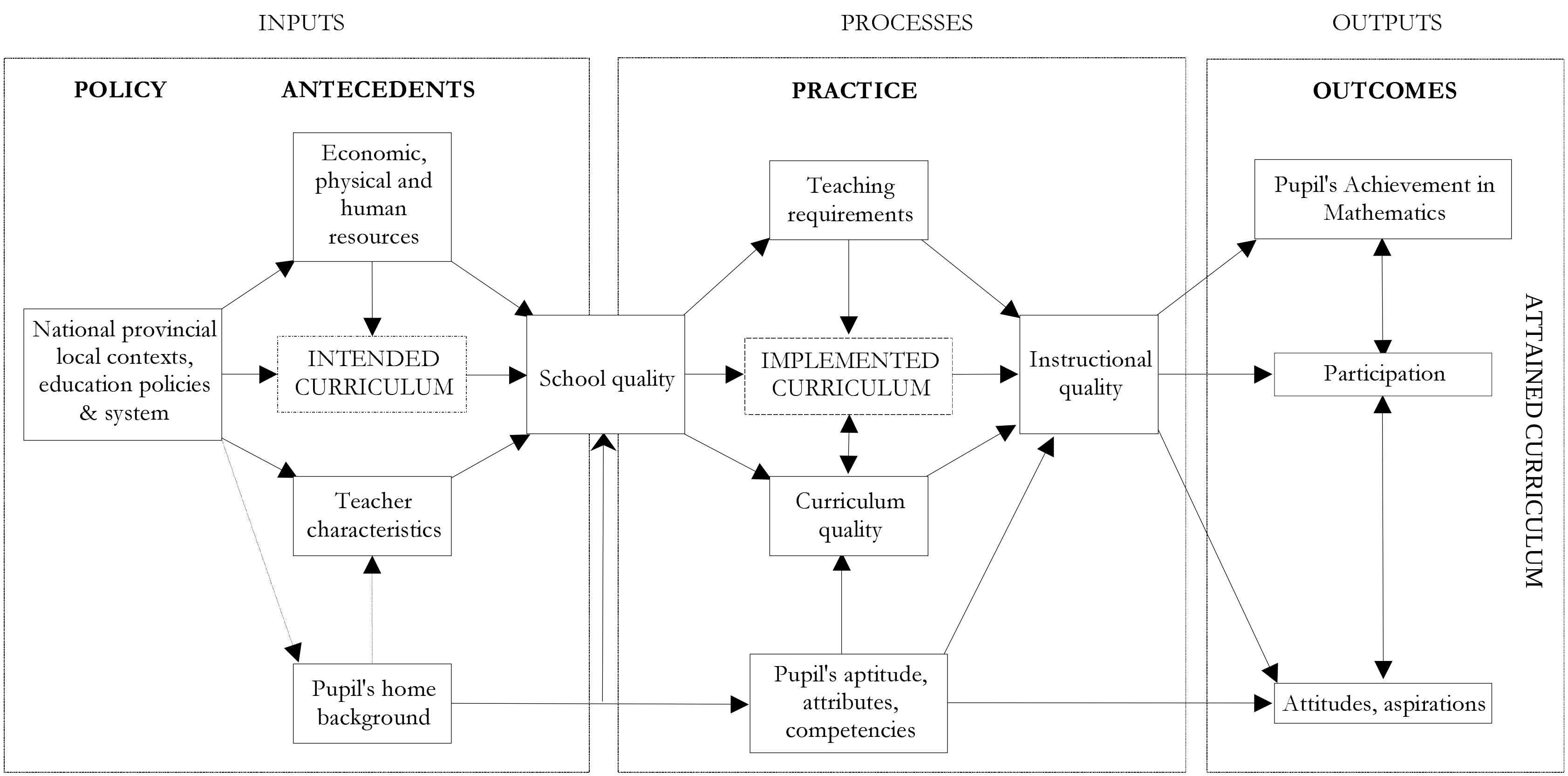


Figure 5.3

Factors related to mathematics achievement

The model for this study (Figure 5.3) presents the education system in terms of inputs, processes and outputs. In the model, the *inputs* are depicted in terms of *policy* as well as *antecedents*. *Policy* relates to the education policies on national, provincial and local level that have an impact on what pupils are supposed to learn, namely the *intended curricula*. *Antecedents* include the financial and other resources supplied to different levels of the system, as well as, the quality of the teachers and the background of the pupils.

The *inputs* into the system affect all the processes of education directly and indirectly. Different *processes* (relating to what is taught and how it is taught) take place within the schools, and inside the classrooms in terms of curriculum, teaching (in the meaning of the context) and instruction. The *outputs* eventuate in terms of the achievement of pupils in specific subjects such as mathematics, participation in class and school activities, and finally pupils' attitudes towards subjects and schooling and aspirations for the future.

School quality refers to how well such aspects such as organisational management and development, governance, financial management, parent and community support, human resource management, instructional time, the organised curriculum, school administration, effective support from the education system (on national, provincial and local levels), physical resources, school profile and schools' previous achievement, are successfully harnessed and/or organised and/or managed. As school quality is partly determined by input variables and partly by the quality of organisation and management of the school, it is depicted on the borderline of inputs and processes.

Implemented curriculum is essentially what is actually taught by the teacher in practice in the classroom as opposed to what is supposed to be taught as laid down in policy. It can be considered the result of a number of components.
Teaching requirements relates mainly to teaching load, class size, demands on time, and teachers perceptions of working conditions, autonomy and collegiality. *Curriculum quality* refers to the "what " of mathematics education. This element covers not only the contents, topics, processes and skills that pupils learn, but also the breadth and depth of the content that is taught, the way that the teachers organise, sequence and present it, and the textbooks and the materials that teachers select and use.
Pupils' aptitude, attributes and competencies relate to the individual characteristics of the pupils in terms of their intellectual development, cognitive ability and skills in the area of mathematics.

Instructional quality refers to the "how" of mathematics education and is supposed to be determined by all other factors at this level. It consists of policies, practices and social climate in the mathematics classes. It also refers to the interaction of teachers and pupils within the class.

The *attained curriculum* encompasses all outcomes of the education processes.
The most obvious outcome of the education is that of the pupils' performance in a subject area, in this case *achievement in mathematics*. This is usually reflected in achievement scores. A second projected outcome is that of pupil *participation*, which relates to the degree and nature of pupils' participation in the classroom and generally in the school activities. The third desired important outcome is pupils' improved *attitudes* and *aspirations* towards education, specific subject areas, schooling and the future.

The model in Figure 5.3 serves as an important theoretical and conceptual basis for the analysis of the TIMSS-R data. As data were collected on a number of education levels, school, classroom and student-level, the model provides a guide to explore the causal links for the pupils' achievement.

5.2 RESEARCH QUESTIONS

The main question in this research is: *What are the main factors that influence pupils' performance in mathematics?*
To provide the context to address this question, it is important to describe the performance, participation and background characteristics of the system. Therefore the study was divided into two phases in which phase one provides this description of the pupils' mathematics and English results as well as potential factors influencing mathematics performance. Phase two analyses and identifies the main factors influencing achievement in mathematics. Arising from the conceptual framework in Figure 5.3 a number of specific operational research questions for Phases 1 and 2 of the study can specified.

Phase 1: Descriptive research questions
The two main questions in phase one are:

1. Who were the South African participants in TIMSS-R?
2. How did the South African pupils perform in the mathematics and English tests?

The specific research questions following from the conceptual framework will direct the study in phase 1 and they will be addressed in chapter 7:

1. Who are the pupils, teachers and schools who participated in TIMSS-R?

To answer this question, information concerning the background of the pupils, of the teachers and background information about the schools and their principals will be described. This question relates directly to the elements in the conceptual framework depicting teachers' characteristics, pupils' characteristics and school quality (in Figure 5.3). As part of the description, constructs are derived from the data, such as a scale for attitude or possessions in the home. This description of the population participating in TIMSS-R provides a rich context for understanding the exploration in Phase 2.

2. How did South African pupils perform in the TIMSS-R mathematics test?

This question is related to the attained curriculum (as illustrated in Figure 5.3). The overall results for mathematics are described in general. These results are described by province, by language of instruction in the school, by gender, and in terms of the sub-tests in mathematics described earlier.

3. How does the performance of the South African pupils compare with pupils from other countries?

Also related to the attained curriculum South Africa's overall results are compared to those of the other countries in the study and thereafter a number of countries will be selected for a more detailed comparison with the South African pupils (for example on sub-tests).

4. How does the performance of the South African pupils in 1998 compare with the performance of the South African pupils in 1995?

This question addresses the longitudinal data provided by TIMSS-R and refers directly to the attained curriculum and pupil achievement in Figure 5.3. It is especially relevant given significant political, economic and social changes that have developed after the first democratic elections in this country (in 1994). South Africa took part in TIMSS in 1995 and TIMSS-R is intended as a replication study. A number of trends are explored on a general level in terms of the results (for example, achievement in algebra in 1998 compared to 1995).

5. How do pupils from different language groups perform in the mathematics test?

Figure 5.3 indicates the relationship of pupil background to pupil achievement and this question seeks to establish the nature and extent of that. In 1995, about 80%

and in 1999, 73% of the South African pupils wrote the test in a language that was not their main language and there were indications that this affected their performance negatively. This question is the first of a number in this study probing this topic. An analysis of pupils' performance on the mathematics sub-tests, on multiple-choice items and free-response items, in terms of performance expectations will be described.

6. How did pupils perform in the English Language proficiency test?

The extent of the pupils' aptitude in English is analysed and described. As a national option in the TIMSS-R study, every South African pupil completed a written skills and language usage test. The performance of the pupils in this test indicates a measure of language proficiency in English. Therefore the South African pupils participating in TIMSS-R will be described in terms of these proficiency levels according to the classifications given by the Human Science Research Council on these tests.

7. What exposure to English do pupils who do not have English as main language have?

A description of the relationship is sought between the pupils' environment (as depicted by *National, Provincial and Local Context….*) and the pupils' home background (clearly illustrated in Figure 5.3). A number of questions were added as national options to the pupils and teachers questionnaires to determine the answer to this question. This is of particular interest regarding pupils who do not speak English or Afrikaans as their main language at home and will be described in Phase one. The relationship between that exposure to the language and their proficiency in English will be explored in Phase 2 of this study.

Phase 2: Exploratory analysis

As mentioned previously, phase 2 is an exploratory phase of the study driven by the central research question, namely *what are the factors influencing mathematics achievement and performance of South African pupils in TIMSS-R*? The results of this analysis are reported in chapters 8 and 9. A number of specific questions will guide the research in this phase:

1. What are the factors that have been found in research previously conducted that influence pupils' performance in mathematics? (see chapter 3);
2. What factors on school level, class-level and student level influence pupils' performance in mathematics? (these are addressed in chapters 8 and 9).

In this phase, an exploration of variables at different levels (see chapter 6 for list of variables at the different levels) will be conducted to address these questions. The aim of the exploration is to identify what are the significant factors at school and classroom-level that affect pupils' performance in mathematics and which of the school and classroom -level factors are most significant in terms of pupils' achievement in mathematics. Special attention will be given here to English language proficiency. In particular, the variables at student-level that affect pupils' performance in mathematics and their English proficiency will be sought.

The aim of the exploration is also to try to ascertain which of the two levels (student-level or class/school-level) has the most influence on pupils' mathematics achievement in the context of South Africa. Evidence from previous research suggests that whilst student-level factors have more influence on pupils' achievement in developed countries (Husén, 1967), school-level factors play a greater role with regard to pupils' achievement in developing countries (Heyneman, 1976; Keeves, 1994). It is therefore believed that school-level factors are likely to play a more significant role with regard to South African Grade 8 pupils' achievement in mathematics than student-level factors. However, it is also recognised that due to the disparity in the home backgrounds of the pupils that the home factors and school factors may play a greater or lesser role depending on the background of different groups of pupils. Therefore, the variables relating to the home background will be explored to determine whether and, if so, how they affect the achievement of different groups of pupils differently. In addition, the school factors will also be investigated to see whether and, if so, how they affect the achievement of different groups of pupils in divergent ways.

One of the factors in particular to be explored in phase 2, is to establish the relationship between second language, communication skills and achievement in mathematics as well as its' relationship to other factors. The pupils who do not speak English or Afrikaans as their main language will be analysed to determine the relationship between their proficiency in the language of the test and their achievement in mathematics. An analysis will be done to see whether there is a significant difference in pupils' achievement between pupils who wrote the test in their home/main language and pupils who wrote in an alternative language. Previous research evidence (see chapter 3) suggests that language plays an important role in pupils' learning (JET, 1998) and that pupils learning and completing tests in an alternative language may be disadvantaged (Clarkson, 1991; Ellerton & Clements, 1991). Finally, the data are explored to investigate the inter-relationship of English language proficiency and other factors.

This study is highly descriptive and exploratory in nature, however a number of hypotheses based on the literature and on the TIMSS results of 1995 will be tested.

- As mentioned earlier, previous research suggests that whilst student-level factors (e.g.: aptitude, ability, perseverance and home background) have more influence on pupils' achievement in developed countries (Husén, 1967), school-level factors (e.g.: time for learning and quality of learning) play a greater role with regard to pupils' achievement in developing countries (Heyneman, 1976). It is suggested here that school-level factors play a more significant role with regard to South African Grade 8 pupils' achievement in mathematics than student-level factors.
- Secondly the research evidence also suggests that language plays an important role in pupils' learning and that pupils learning in a second language may be disadvantaged. It is hypothesised therefore that pupils performing poorly in the English language test will also perform poorly in the mathematics test.

These will be discussed in chapters 8 and 9 on the basis of the results of the partial least square and multi-level analysis.

5.3 SOME DESIGN ISSUES

In this section the sample, the instruments, procedures and the analysis plan that were used for this study. These will only include the specifics beyond the general design of TIMSS-R and those already mentioned in Chapter 4.

Sample

The study was undertaken using the South African sample in TIMSS-Repeat 1998 of 225 schools (including about 10 000 pupils). The TIMSS requirements stipulated that a minimum of 150 schools be tested and that a minimum of one class (preferably one whole class) per school be tested. The South African sample was expanded to 225 to accommodate the inter-provincial analysis required. The sample drawn was nationally representative and was stratified by province, school sector and medium of instruction. South Africa's sampling frame included 7 234 (secondary) schools with 968 857 pupils. In the first sampling phase, 225 schools were selected from all nine provinces (the explicit strata). Additional implicit strata included the language of instruction (English or Afrikaans) and school funding (state, state-aided or private). Equal sample allocation was used for the explicit strata to produce regional estimates. Special explicit strata was also included in Gauteng province to produce the schools required for the field trial conducted in English schools only.

For the second phase of sampling, information was collected regarding the number of Grade 8 mathematics classes and pupils in the selected schools. Thereafter, the procedures for randomly selecting whole classes were performed according to the TIMSS-R guidelines, resulting in one intact mathematics class per school being selected. The results of the South African sample are summarised in Table 5.1. The realised sample was monitored and approved by the IEA and therefore national estimates can be given (meaning that the results can be generalised from the sample to the population).

Ultimately 200 schools participated, although six schools were removed from the data as the sampling on classroom level was unacceptable – principals had insisted on testing a different class to the one sampled, despite all efforts to the contrary. This resulted in 194 schools and 8 147 pupils being included in the international dataset for analysis. Although 646 pupils who were sampled for testing were absent on the day of the test, South Africa achieved a 93% participation rate at the student level.

Excellent participation rates were attained in Eastern Cape where 100% of the sample participated. KwaZulu-Natal and Western Cape also recorded good participation rates. Unfortunately, lack of co-operation from and mismanagement by the schools in North West and Gauteng resulted in a considerably lower sample being reached in those provinces. While schools in the other provinces were generally enthusiastic about participating in the study, the schools in North West in particular (which had the highest number of non-participating schools, 9) were reluctant to participate and saw the study as a threat to them. Overall, South Africa achieved an 85% response rate (Howie, 2001, p. 12-13).

Table 5.1
School sampling status for South Africa in TIMSS-R

Province (Explicit stratum)	**Total sampled schools**	**Ineligible schools**	**Participating schools** *Sampled*	*1st replacement*	*2nd replacement*	**Non participating schools**
Eastern Cape	25	0	25	0	0	0
Free State	25	1	19	2	0	3
Gauteng	25	2	15	2	1	5
KwaZulu-Natal	25	0	23	2	0	0
Mpumalanga	25	1	20	1	0	3
North West	25	0	15	1	0	9
Northern Cape	25	1	22	0	0	2
Northern*	25	0	21	1	0	3
Western Cape	25	1	23	1	0	0
Total	225	6	183	10	1	25

Source: Howie, 2001, p.12.

Note: *Now the Limpopo Province.

Instruments

Many concerns have been raised nationally about employing an international test in the South African context. The issue of fairness and the quality of the tests raised some debates about South Africa's participation. The international study centre conducted an analysis of the content of the items and compared it to the content coverage of each country (test-curriculum match analysis (see Mullis et al, 2000). Amazingly, pupils internationally performed very similarly on the international test as they did on items that their own curriculum covered. For example, for South Africa, (on average) pupils got 20% of the South African mathematics questions matching the SA curriculum correct compared to 21% of all the international questions. In contrast for mathematics, Korea achieved 73% correct on their own questions and 73% on the international questions. Jordan, who had 41% on their own questions, achieved 38% on the international questions. In terms of actual questions that South African pupils should have been exposed to in grade 8, 83% of the mathematics questions in the international test were in the South African curriculum for grade 8, according to the South African national department officials who analysed the test questions. The curriculum analysis provides an indication of what pupils are supposed to learn in each of the countries based on the information from the Department of Education. In mathematics, 10 of the 38 countries had fewer questions fitting their national mathematics curriculum than South Africa, but all of them performed significantly better than South Africa both on their 'national questions' and on the test as a whole.

In addition to the instruments internationally prescribed for TIMSS-R (see 4.3), an English language proficiency test was included in the South African study as a nation option specifically for South African pupils. This instrument had previously been validated by the Human Sciences Research Council and standardised for Grade 8 Second Language pupils in South African schools (HSRC, 1990). At the time of the TIMSS-R study, this test was the only standardised South African second language test at the Grade 8 level that could be found. However, two language education experts who evaluated the test believe that in some items the language of the test is perhaps old fashioned in nature and the language in some items is decontextualised. Nonetheless, both concluded that the results would probably correlate highly with a more modern test and therefore felt that it was still valid. In addition, questions were also included in the TIMSS-R pupils and teacher questionnaires, to ascertain the extent and level to which the pupils are exposed to English. They included pupils' home language, ethnic group, the language spoken predominantly by the pupils in the mathematics class, the language used by the mathematics teacher in class, media languages pupils are exposed to and the language of their reading materials.

For this study, information from the student questionnaire, mathematics teacher questionnaire, school principals; questionnaire and the data from the mathematics achievement test and the English language test were used in the analysis.

Procedures

As was discussed in Chapter 4, the data were collected during October and November 1998. Thereafter an extensive literature survey was undertaken to look for information regarding the relationship between language and achievement in mathematics as well as characteristics of schools, teachers and pupils and other factors related to pupils' performance in mathematics, the results of which are reflected in the conceptual framework for the study and in the choices of variables and analysis methods for Phase 2 of the research.

The first phase of the study involved a descriptive analysis of the data. Thereafter, inferential statistics were applied and path models were first explored using Partial Least Squares (PLS) analysis. The results of PLS were analysed before applying multi-level analysis (i.e.: Multi-level analysis using MLwiN). One limitation of the study is that system-level variables cannot be included in the statistical analysis as none were included in the study. The reporting of these is therefore only descriptive in nature and will be based on current policy documents regarding the South African Education System.

Analysis Plan

The first step in the analysis was to produce univariates of all the possible school-, class- and student-level factors linked to the research questions. This was followed by an exploratory factor analysis and scale analysis to develop good quality constructs (such as possessions in the home). The results of this descriptive analysis are described in chapter 7. These analyses were followed by a correlation matrix of all variables and constructs, which were expected to be important for studying possible relationships of background variables to achievement. Given that there were a number of variables influencing pupils' achievement and that some of these are intricately inter-related, Partial Least Squares (PLS) (a detailed description of the method is given in chapter 6 and the results of the PLS analysis are given in chapter 8) was used initially to analyse the strength and the direction of relationships between student-level factors and achievement and also those between classroom and school-level and pupils' achievement in mathematics. As PLS is only suited to analysing data on a single level (e.g., only student level data or only school level data) at any given time, PLS was followed by the application of multilevel modelling using MLwiN whereby both the school and class-level and the student level data were analysed simultaneously to identify and compare the effect overall of factors at different levels on achievement. A detailed description of the multi-level analysis is presented in chapter 6 whilst the results of this analysis may be found in chapter 9.

CHAPTER 6
Data analysis methods used in the study

This study utilised a number of data analysis methods in order to adequately address the research questions. Partial Least Squares Analysis (PLS) was first applied to identify variables that had significant paths to Grade 8 pupils' mathematics scores. This was done on student-level, classroom-level, school-level resulting in three separate models being produced. The classroom and school-level models were then combined and the most significant variables identified for further analysis using multilevel analysis. The Multilevel analysis (MLN) was then conducted using the MLwiN software which was then able to indicate how much of the variance in the mathematics scores could be explained once all the variables (on student and on school-level) were included, in addition to revealing which were the most significant variables included in the final model.

In this chapter, the analytical methods Partial Least Squares (PLS) Analysis and multi-level modelling (MLn) that were used for this study are discussed in more detail. Firstly a description of PLS will be given in 6.1 providing information on the technique and then the rationale and specific applications of PLS in this study will be discussed. The programme PLSPATH that was used to apply PLS in the analysis is also described in this section. The hypothesised models on student-level and class-level and school level that were designed for the study are discussed in 6.2. In 6.3, a description is given of multi-level modelling and the programme MLwiN as well as the methods employed in this research.

6.1 PARTIAL LEAST SQUARES ANALYSIS (PLS)

The natural complexity of human behaviour and social systems provides researchers with constant challenges to find explanations for such complexities. Applied to education, there is the challenge to find explanations for outcomes of teaching and learning processes, resulting in increasing needs for research approaches and techniques that may assist researchers in meeting these challenges. The development of more sophisticated statistical procedures for investigating complex relationships between variables, such as path analysis, causal modelling and linear structural relations analysis resulted in approaches to investigate the relationships between contextual variables and achievement also in education.

Path analysis as one form of multivariate analysis that explores causal relations amongst different factors (variables) and represents these by means of graphic path diagrams. These diagrams or causal models illustrate the "paths" along which the causal influences flow. This type of analysis allows researchers to estimate or predict both the direct and indirect effects of a set of independent variables (with each path taking in account the effects of all other variables) on a dependent variable (such as a mathematics achievement score) in a way that cannot be done using ordinary multiple regression analysis. Research using path analysis has grown tremendously during the past twenty years with the increasing use of computers that alleviate the huge task and burden of doing the statistical computations manually.

One technique used to estimate path models is Partial Least Squares (PLS) analysis. PLS was formally presented by Wold (1982) as a technique for estimating path models in the field of economics and it was only later applied in sociology and education. For detailed technical information the reader is referred to Wold (1982), Noonan and Wold (1983 and 1988), Sellin (1989, 1992), Cheung and Keeves (1990), Falk and Miller (1992), Campbell (1996) and Sellin and Keeves (1997). In this study, PLS is used as the first stage of exploration in identifying factors on a student level as well as on a combined class and school-level that predict the performance of South African Grade 8 students in mathematics in TIMSS-R. For this application the programme PLSPath (see Sellin, 1990a) has been used. In this section the technique, its characteristics, usefulness and advantages are briefly explained.

PLS characterised

PLS is able to analyse complex systems in a quantitative way in order to understand and to explore the relationship between (independent and dependent) variables that one cannot easily measure directly. In, for example, Figure 6.1 (see page 93) the mathematics score "*mathach*" is the *dependent* variable, and many *independent* variables are supposed or assumed to have a direct or indirect effect on the independent variable. This influence is expressed through a '*path*' (indicated by an arrow) in the diagram or the model, while a coefficient (the so-called path coefficient), which is represented by a decimal point (e.g.: .16), indicates the strength of the relationship.

Some variables cannot be observed directly; they are called *latent* variables. However, latent variables can be estimated or measured by observable or *manifest* variables.

This can be done in two ways. One example of a *latent* variable in Figure 6.1 is that of the "home" (characterising the home situation of students), which is reflected by two *manifest* or observed variables, namely "famsize" (the number of people living in the home) and "adults" (whether or not the student has both parents, including step-parents living in the home with the student). These two manifest variables cannot simply be added together but are included separately in the analysis (utilising certain mathematical procedures) resulting in the construct "home". A second example of a latent or unobserved variable is that of "*lanlearn*" (the language of learning in the classroom). In this case, this variable is the sum score of two (manifest or observed) variables, namely "*stlang_1*" (the language most often used by the student in the classroom to ask questions in a mathematics class; called 'student' in Figure 6.1)) and "*tlang_1*" (the language most often used by the teacher when introducing a new topic or explaining difficult topics to the students in a mathematics class; called 'teacher' in Figure 6.1)).

The relationship described in the second example of a latent variable (here "lanlearn") as being the combined sum scores of two or more manifest or observed variables (here "stlang_1" and "tlang_1") is called in PLS the *inward mode*. The example of the latent variable like "home" as not being just the combined sum score, but a more complex reflection of two or more manifest variables (here "famsize" and "parent") is defined in PLS to be in an *outward mode*. In the inward mode the latent variable is regressed on the manifest variables, while in the outward mode, the manifest variables are regressed on the latent variables. In the inward mode the manifest variables are combined in an additive way, while in the outward mode, the manifest variables are combined as alternatives that are each controlled for the effects of the others (Keeves, personal communication).

Latent variables may also relate to a 'single' manifest variable (for instance, the latent variable "gender" whose manifest variable is "sex"), and these are referred by PLS as being *unities* (i.e. one manifest variable forms one latent variable).

In principle, a PLS model is defined by two sets of linear equations, called the outer model and the inner model (Noonan & Wold, 1988; Sellin, 1995). The *outer model* specifies how latent (unobserved) variables (LVs) that are either in an outward or an inward mode are linked to their associated observed or manifest variables (MVs) (such as "home' and "lanlearn' in the above examples). The *inner model* defines the hypothesised relationships between all the unobserved or latent variables (LVs)(such as between "*home*", "*lanlearn*" and others in Figure 6.1).

A convention has been developed (Falk, 1987) whereby latent and manifest variables are illustrated diagrammatically in the path model (see student-level model Figure 6.1). Latent variables (as can be seen by "*home*" and "*lanlearn*" are summarised within *ellipses* and manifest variables (such as stlang_1 and "famsize") are illustrated within *rectangles*. *Arrows* (one-headed) indicate the direction of the relationships between variables and are interpreted as predictive or causal relations. In the outer model the arrows represent the outward mode variables from the LV to the MVs, while the reverse applies for the inward mode variables. An arrow in the inner model marked in a single direction indicates the relationship between two LVs (inner model) in the path model. The arrow runs from the determining variable to the variable dependent on it such as from "*lanlearn*" to "maths" meaning that it specified in the hypothesised model that the level and frequency of language of learning used in the classroom may predict (part of) students' achievement in mathematics. The determining variables, which are not dependent on any other variables, are called *exogenous variables* (Keeves, 1988). These exogenous variables (an example being the age of the student) are indicated in the model by having no unidirectional arrow pointing towards the variables. In comparison, *endogenous variables* (Keeves, 1988) are those dependent on any other variables (such as "*attitude*", "*home*" and "*lanlearn*") and are illustrated by means of one or more unidirectional arrows pointing towards them.

Advantages and limitations of using PLS

Like other statistical techniques and procedures, there are a number of assumptions underlying the use of path analysis. Pizzini and Shephardson (1992, p. 249-250) summarised five assumptions that were outlined by Pehadzur (1982):

1. The relationships among variables are linear, additive and causal;
2. All relevant variables are included in the model;
3. There is a causal flow in the relations between variables in the model;
4. The variables are measured on an interval scale;
5. The variables are measured without error.

These assumptions are quite heavy and many data sets do not meet them all. Sometimes problems can be addressed. For example, a nominal variable can be 'defined' as an interval variable ('gender' can be defined as 'female = 1' and 'male = 2'). In other cases, such as assumption 5, it is often not possible to realise the condition, resulting in an extra reason to be careful with drawing conclusions too categorically, which is in line with the exploratory character of PLS.

Amongst several advantages of this technique, the key feature noted is the explicit estimation by means of the least squares method of each latent variable score (by the weighted aggregate of its indicators). Sellin (1995) recommends the use of PLS where the research is investigating complex models in an exploratory rather than a confirmatory manner.

"*Soft modelling*" (that is estimating latent variables by one or more manifest variables) is considered to be particularly useful by Noonan and Wold (1983) when operating with data from large and complex systems (such as school systems in an interdisciplinary situation with vast quantities of data) in an exploratory fashion. PLS considers the optimal linear relationship between variables and is able to provide the parameter estimates for the parameters of the model (such as loadings, communality, redundancy and tolerance; they will be introduced in 6.3) both quickly and efficiently.

PLS can handle many variables and composite variables simultaneously; can provide an appropriate form of information reduction; is flexible; and can provide estimates of direct and mediated effects. Ultimately, the purpose of PLS is to increase the predictive power of the indicators in the model being investigated.

Jacobs (1991) and Bukowski, Hoza and Boivin (1993) argued that PLS is an ideal procedure for developing a predictively powerful path-model, because it provides a so-called index of the adequacy of the model, shows the strength of each individual path in the model, and examines the direct and indirect relations amongst variables. The indices of adequacy (see Sellin & Keeves, 1997, p. 637-638) allow one to conclude whether or not the model provides an accurate representation of the relations between variables in the model. In this type of path model, specific variables can be identified as being either causes or effects and the strengths of particular paths show in turn the strengths of the linked variables to each other.

Since PLS was developed in the 1970s, many researchers (Afrassa, 1998; Bos, 2002; Janssen Reinen, 1996; Keeves, 1986; Lietz, 1995; Mohandas, 1999; Noonan & Wold, 1988; and Sellin, 1995; amongst others) have used the PLS approach to analyse data from IEA studies.

Obviously PLS also has its limitations and these are also discussed in a number of papers (amongst others by Anderson & Gerbing, 1988; Lietz, 1995). One criticism is that of the absence of an overall test of significance or various goodness-of-fit indices, although this is countered by arguments that such tests should be treated with caution as they assume the independence of observations and multivariate normal distribution, which is rarely the case. PLSPATH (the computer programme for PLS analysis used in this study) actually provides a jack-knifing method, which calculates estimates of standard errors. However, with the TIMSS data this is problematic as the jack-knifing method used in this study assumes a simple random sample, which is not the case for the South African TIMSS sample. PLS itself does not rely on tests of statistical significance to guide the model specification and therefore the onus is on the researcher to ascertain any problems with the specification of the model. It is for this reason that each user has to determine the critical values above which estimates of latent variables will only be included in further analyses, as well as minimum values for path coefficients. Whilst PLS maximises the internal consistency and reliability of the latent variables, it does not allow unmeasured correlations between manifest variables to be modelled (Sellin & Keeves, 1997).

PLS compared to other methods

Another commonly used approach to path analysis is LISREL using the Maximum Likelihood estimation method. Both PLS and LISREL are estimation methods for path analysis with latent variables indirectly observed by multiple indicators. However, there are differences between the two methods (according to Noonan & Wold (1983) in optimisation criteria, the data, scale of models, generalisation, and underlying assumptions) and one is more appropriate than the other in certain situations. Whilst LISREL is parameter-oriented, that is aiming at high accuracy in the estimation of the parameters, PLS is prediction-oriented, aiming at high accuracy in prediction of paths. According to Noonan and Wold (1983) LISREL is more appropriately used in the analysis of smaller models (i.e. small number of variables) where separate parameters have operative use and the theory is strong. In contrast, PLS is more suitable for larger and more complex models where the emphasis is on prediction and the theory is not as well developed, such as the interdisciplinary studies of large, complex school systems. In practice, LISREL is typically limited to fewer than 15 inner variables and some 40 variables in the inner model as opposed to PLS where only the computer restricts the size of the model or the number of parameters (Noonan & Wold, 1983). Another difference lies in the fact that using LISREL the latent variable has just one dimension compared to PLS where multiple dimensions can be estimated consecutively (such as in the variable "home" discussed above) (Noonan & Wold, 1983). Finally, in Maximum Likelihood estimation in LISREL, it is assumed that observations under analysis are governed by a specified joint multivariate distribution subject to independent observations, whereas Least Squares estimation in PLS is free of assumptions about the distribution of the variables except for the prediction specification and is devoid of assumptions regarding the independence of observations.

Therefore, whilst PLS clearly has its limitations as specified and discussed above, nonetheless the design of this study required a technique that was flexible, fairly robust, fast and allowed an exploratory analysis, all of which PLS matches. Results from the PLS analysis would determine the strength and direction of relationships that were appropriate for inclusion in the further analysis when applying the multi-level analysis. As the multi-level analysis does not allow for estimating latent variables, the results and weightings of manifest variables in PLS could be used in the subsequent multi-level analysis.

6.2 MODELS OF STUDENT-LEVEL, CLASS AND SCHOOL LEVEL FACTORS INFLUENCING MATHEMATICS ACHIEVEMENT

The first step in the analysis resulted in three different models (on student-level, class-level and school-level) being developed that hypothesised the relationships between background variables and students' achievement in mathematics. These models formed the starting point for the PLS analyses of the South African TIMSS-R data, the results of which are reported in Ch.8. They were developed informed by the conceptual model for the study, the literature and by the researcher's knowledge of the context. However, most of the information derived from the literature related to studies outside of South Africa and no similar study could be found in South Africa. Studies in South Africa of factors related to mathematics achievement tended to be small scale, qualitative projects whose results were not generalisable. However, where possible, factors suggested by these studies were incorporated for analysis.

Whilst only one class per school was tested for TIMSS-R in South Africa and therefore essentially class and school represented only one level, technical restrictions on the number of latent variables suggested the need to explore the data on each level separately and then combine the class and school level data (including the strongest direct paths in both models) into one single model. The technical restrictions meant that one latent variable required at least 15 cases (respondents) and as the South African dataset for mathematics teachers only had 189 cases and the school level dataset only 188 cases, it was clear that the number of latent variables would be greatly reduced by this restriction. Having an initial exploration on both levels permitted double the number of latent variables being explored before these were combined. On the student level, there was no such restriction as the final dataset had more than 8 000 cases (8 141) and therefore a large number of latent variables could be included in the analysis. Each of these models will be discussed separately in the remaining of this section.

6.2.1 Student-level model

The primary research question addressed by this model (see Figure 6.1) is*: "what factors on student level have direct and/or indirect effects on student achievement in mathematics at Grade 8 in South Africa?"*

In Figure 6.1, it is hypothesised that 22 factors influence pupils' achievement in mathematics, namely 1) race of the pupil (*race*), 2) age of the pupil (*age*), 3) gender of the pupil (*sex*), 4) language used in the home (*lang*), 5) home background (*home*), 6) parents' highest levels of education (*pareduc*), 7) books in the home (*book*), 8) socio-economic status (*SES*), 9) the availability of learning equipment (*learneq*), 10) learning environment (*lenvment*), 11) language of learning in the classroom (*lanlearn*), 12) teaching methods (*tstyle*), 13) the importance with which pupils (their mother and friends) regard mathematics (*impmaths*), 14) the importance with which students regard English as a subject (*impengl*), 15) how much time was spent on homework (*homework*), 16) extra lessons in mathematics (*lessons*), 17) aspirations for further education (*aspire*), 18) the frequency with which pupils and their friends bunk school (*attend*), 19) pupils' self-concept in mathematics (*selfcnpt*), 20) pupils' success attribution (*sucattrb*), 21) pupils' attitude towards the subject (*attitude*), 22) their proficiency in English (*engtest*).

It is also hypothesised that a number of factors also have indirect effects on pupils' achievement such as *race, SES, age, home and attitude* through factors such as *lessons, aspire, and attend* (see Figure 6.1).

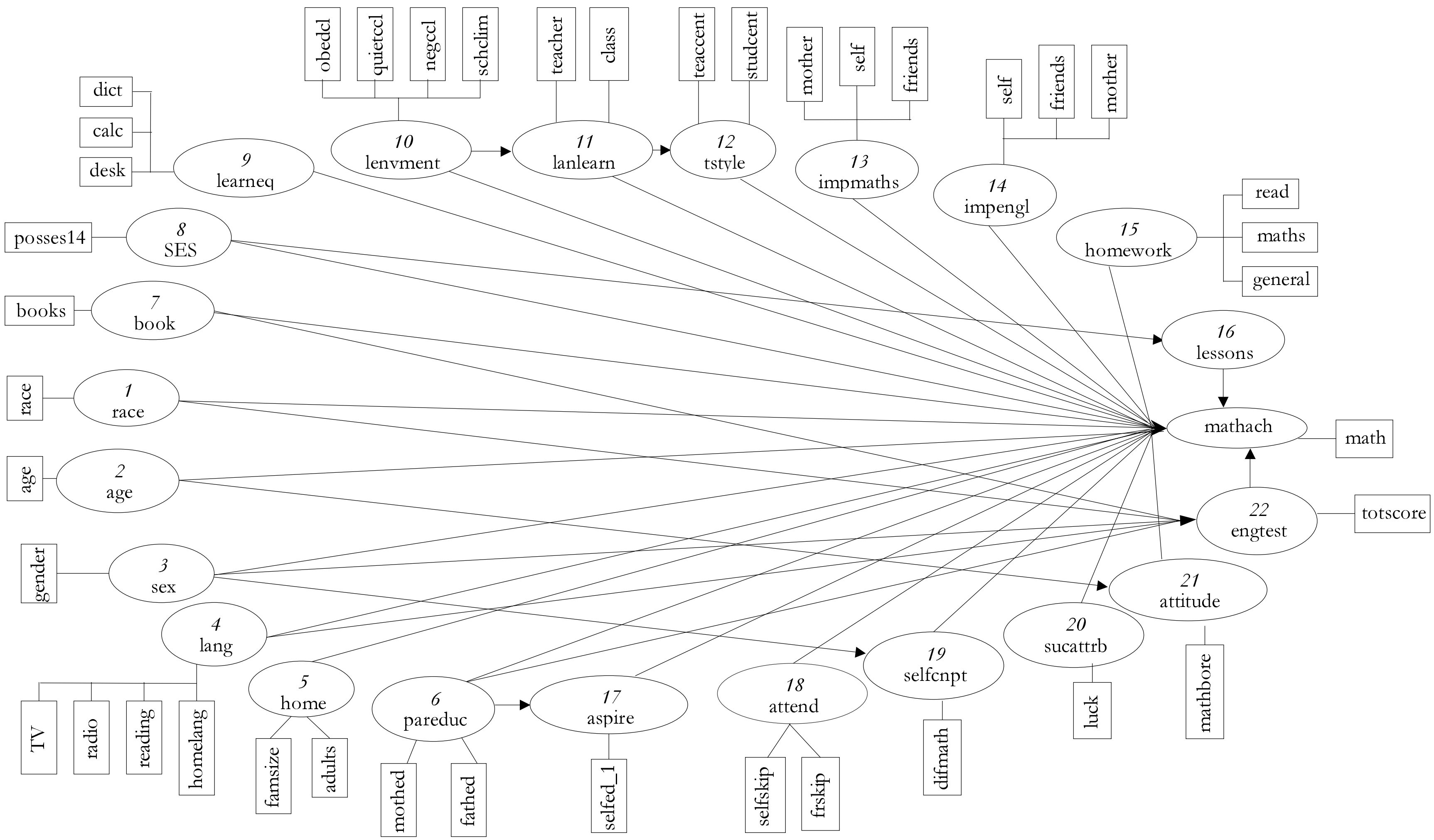


Figure 6.1
Initial student-level model

6.2.2 Classroom-level model

The classroom-level model (see Figure 6.2) is derived from the research question: "*what factors on classroom-level have direct and/or indirect effects on student achievement in mathematics at Grade 8 in South Africa*?".

Fourteen factors are hypothesised to have direct and indirect effects on students' achievement, namely: 1) teachers' background (*background*), 2) number of pupils in class that was tested (*classize*), 3) resources (*resources*), 4) limitations (*limitations*), 5) students' language proficiency in the language of learning (*agg Engtest*), 6) language of students (*agg lang*), 7) students SES (*agg SES*), 8) mathematics topics covered in class (*topics*), 9) time on task (*time*) 10) teachers' confidence (*confidence*), 11) teachers' beliefs (*beliefs*), 12) attitude towards teaching (*attitude*), 13) teachers' activities (*activities*), and 14) teaching style (*tstyle*). Based on the literature, some of these factors are also believed to have indirect effects on students' achievement such as teachers' *beliefs*, their *confidence*, and their *attitude*.

6.2.3 School-level model

At the school level (see Figure 6.3), the main research question is "*what factors on school-level have direct and/or indirect effects on student achievement in mathematics at Grade 8 in South Africa*?"

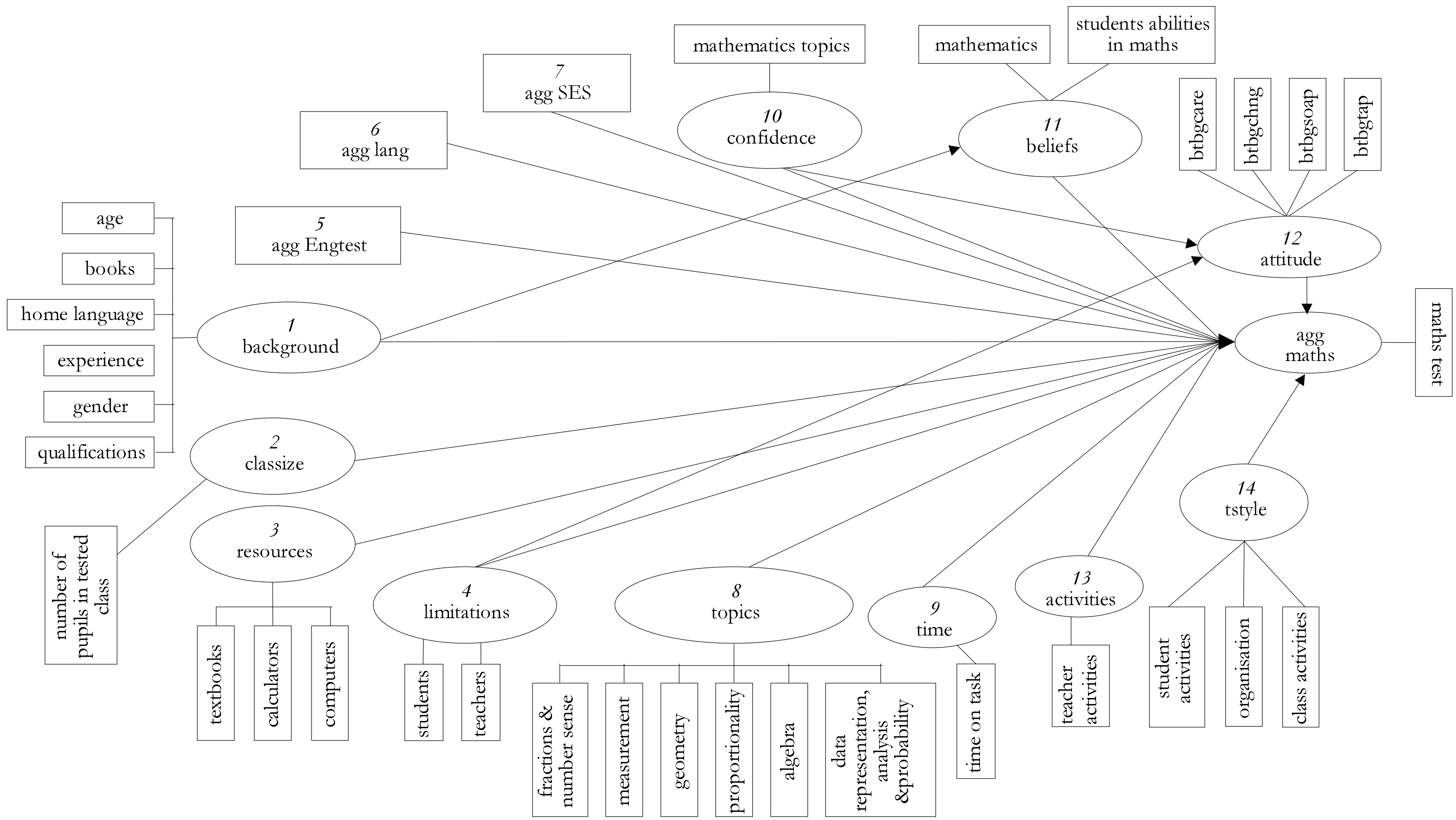


Figure 6.2
Initial classroom-level model

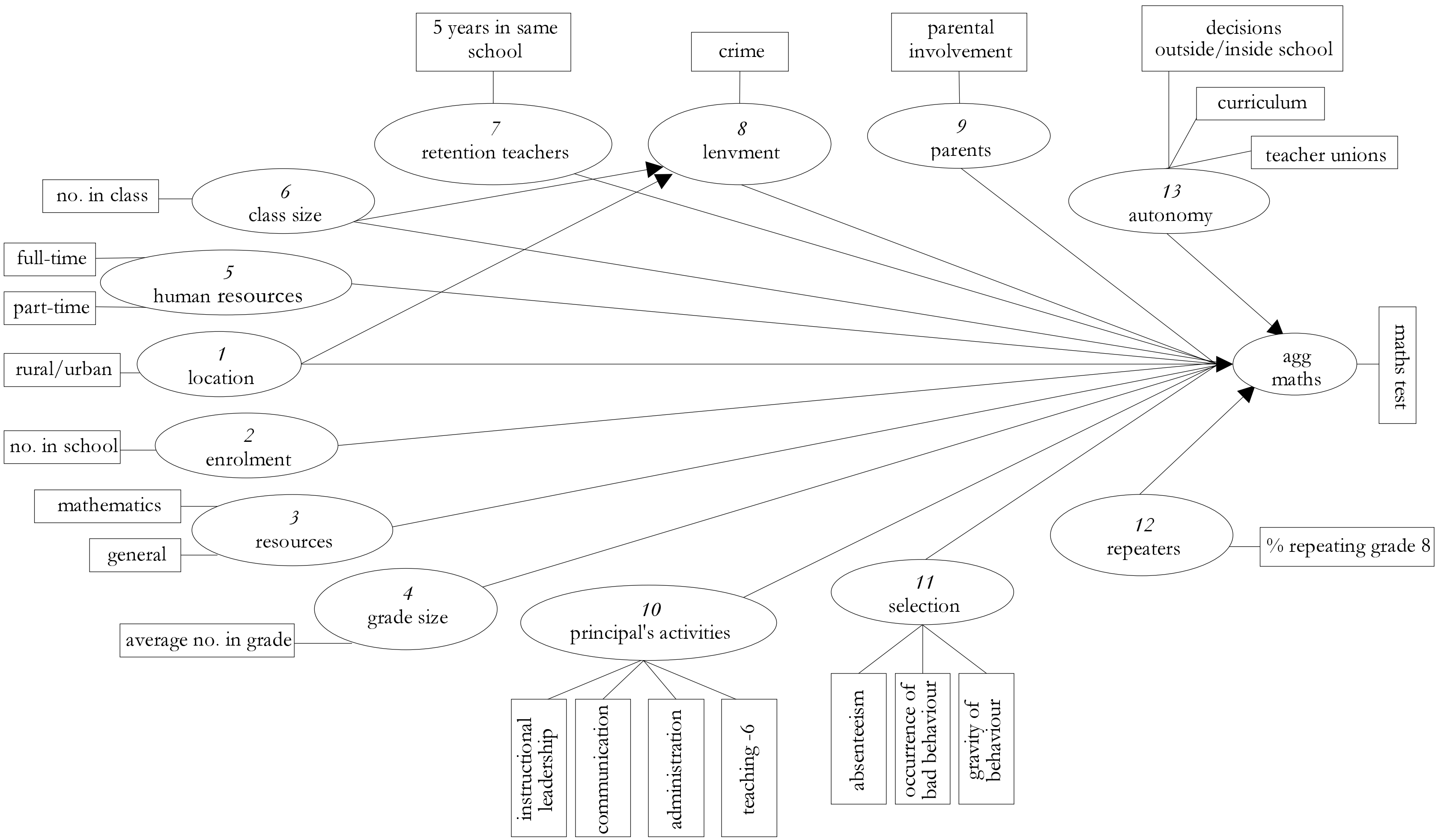


Figure 6.3

Initial school-level model

Thirteen factors are believed to have direct and indirect effects on students' achievement in this model. These are 1) geographic location of the school- rural or urban (*location*), 2) number of students enrolled in the school (*enrolment*), 3) limited resources faced by the school (*resources*) 4) number of students in grade 8 in the school (*grade size*), 5) the number of teachers in the school (*human resources*), 6) average number of students in grade 8 classes in the school (*class size*), 7) retention of the teaching staff in the school (*retention teachers*), 8) the learning environment in the school (*lenvment*), 9) parental involvement in the school (*parents*) 10) principals' activities in the school (*principal's activities*), 11) admission procedures to the school (*selection*), 12) number of repeaters in grade 8 (*repeaters*), and finally 13) the autonomy of the school (*autonomy*). Based on the literature, *classize* and *location* are also believed to have indirect effects on students' achievement.

6.3 BUILDING THE MODELS USING PLSPATH

The computer program PLSPATH was written by Sellin (1989) to employ the PLS technique and Version 3.01 was used for this study. As mentioned earlier (in 6.1), the PLS model is defined by two sets of linear equations, namely the outer model and an inner model. The outer model specifies the way that latent (unobserved) variables (LVs) are linked to their associated observed or manifest variables (MVs) whilst the inner model defines the hypothesised relationships between unobserved or latent variables (LVs). Tuijnman and Keeves (1994) suggested that the principles of *coherence* and *parsimony* appeared appropriate to apply when one is testing the model. *Coherence* shows the degree of agreement between the theoretical considerations and including a path in a model due to its strength estimated in testing the model (expressed in the path coefficient having a value higher than a pre-determined criterion). *Parsimony* refers to the simplicity of a model, and the deletion of a path and a parameter from a model if there are merely tenuous reasons for supporting its inclusion in the model. Both of these are considered important when reducing the number of variables in the model as hypothesised paths are found to be redundant. This is referred to in the literature as *trimming* the model.

As mentioned earlier, PLS is a very flexible technique and therefore by applying PLSPATH allows the hypothesised model to be refined (or trimmed) in subsequent steps according to the preliminary results gathered. In essence this means that MVs and LVs are deleted from that model that do not have significant paths (see the criteria below) in the model. In order to do this and to trim the model, a number of criteria are used, and whilst a detailed discussion of the evaluation and refinement of models is beyond the scope of this study, the most salient points are included here and more detailed accounts may be found in Sellin (1991), Kotte (1992) and Lietz (1995).

The results for the outer model refer to the extent that MVs predict LVs and parameters such as standardised weights, loadings, communality, redundancy and tolerance (see Figure 6.4) are provided in order to do this.

Variable	Weight	Loading	Communality	Redundancy	Tolerance
GENDER	Outward	Exogen	1 MVs		
Sexteach	1.0000	1.0000	1.0000	.0000	.0000
AREA	Outward	Exogen	1 MVs		
sccomm_1	1.0000	1.0000	1.0000	.0000	.0000
AGGLANG	Outward	Exogen	1 MVs		
homela_1	1.0000	1.0000	1.0000	.0000	.0000
AGGSES	Outward	Exogen	1 MVs		
posses_1	1.0000	1.0000	1.0000	.0000	.0000
AGGSELFC	Outward	Endogen	1 MVs		
difmat_1	1.0000	1.0000	1.0000	.3378	.0000
CLASSIZE	Outward	Endogen	1 MVs		
Testsize	1.0000	1.0000	1.0000	.1002	.0000

Figure 6.4
An example of the outer model parameters for PLS

If the weight of the MVs is less than 0.10 or the loading is less than 0.40, it has been recommended (by Pedhazur, 1982; and Keeves, 1992b) to exclude those MVs from the outer model, as otherwise it is felt that they negatively influence the predictive power of the construct. If the loading is equal to or greater than 0.30, the relationship between the MV and its corresponding LV is considered significant (Sellin & Keeves, 1997). If the communality value, which indicates the strength of the outer model and may be calculated by squaring the correlations between the manifest variables and their related latent variables (Sellin, 1989) is greater than 0.30, then the outer model is considered significantly strong (Falk, 1987). If the tolerance value (which is the value indicating possible multi-collinearity within a block of manifest variables in the inward mode) is equal to or greater than 0.50, then caution is needed, meaning that one predictor has a high correlation with some of the other predictors within the block of MVs (see Sellin, 1990b). However this is not the case and no problems are experienced in the outward mode (Keeves, personal communication).

The direct effects (the strength of the relationship between a latent variable and achievement) and the total effects (which includes both the direct and indirect effects on achievement) are the results given for the inner model. Here any path coefficients (beta coefficients) of less than 0.10 are removed from the smaller models (i.e.: classroom level and school level models where there are less than 190 cases) as at this level 0.10 is considered conservative (Cheung & Keeves, 1990; Keeves 1992b; and Sellin 1990b). Given large samples of students Sellin suggests that 0.07 may be used in large samples of students and this was applied in the case of the student-level model. Cohen (1969) provides guidelines for the interpretation of path coefficients that subsequent researchers have followed. Coefficients of between 0.10 and 0.25 are considered weak, those between 0.25 and 0.40 are considered medium strength and any above 0.40 are considered strong. Finally, the inner model diagnostics provide an overview of the appropriateness of the model. The R-square (R^2) value that is given to each of the LVs shows the variance of a construct that is explained once all the previous constructs have been accounted for.

6.4 MULTI-LEVEL ANALYSIS

Whilst PLS serves as a useful exploratory tool, it is unable to take into account the multi-level nature of the education system. That is PLS considers the data on one level and does not take into account the fact that students are clustered in classrooms and that these classrooms reside within a school. Multilevel research or modelling is a research tool that investigates the interaction between variables on the individual (student) level and variables that describe the social groups to which the individuals belong (for example, schools and classrooms). Multilevel modelling was included in this study so that the multilevel nature of the TIMSS-R data could be considered when looking for answering to the question "what factors have direct and/or indirect effects on pupils' mathematics achievement". In this section, the multilevel modelling technique and procedures are briefly characterised while the results are presented in Chapter 9.

6.4.1 Introduction to multilevel modelling

During the 1980s multi-level modelling or hierarchical linear modelling began to emerge as more appropriate tools for data that comprised a "nested" structure (i.e.: students within classes within schools). Multilevel modelling in brief is a tool to model data with complex hierarchical structures taking into account the nested structure of these data. Like PLS, it is used not only in education, but also in medical science, demography, economics and agriculture amongst others.

Different methods of modelling and estimation approaches were developed by Aitkin and Langford (1986), De Leeuw and Kreft (1986), Goldstein (1987), Mason, Wong and Entwistle (1983), and Raudenbush and Bryk (1986). Although the procedures were different, they do share two central features. Firstly, their methods allowed researchers to "formulate and test explicit statistical models for processes occurring within and between educational units" and secondly their methods handle the error in the data so that the multilevel structure of the data is appropriately reflected, "enable specification of appropriate error structures" which include the random intercepts and coefficients (Raudenbush & Bryk, 1994, p. 2590).

Due to the fact that in this study data were collected on three levels – student-level, class-level and school-level, the Multilevel Modelling (MLN) (the technique is described in this chapter and the results in chapter 9) was used to develop a model that adequately reflects the structure in the data. As only one class per school was sampled, only two levels were used in the analysis and therefore a two-level model was developed to distinguish between the variance in mathematics achievement uniquely explained by student-level factors as opposed to the variance uniquely explained by the classroom and school-level factors, while also looking at the interaction between the two levels. See (amongst others) Goldstein (1987), Hox (1995), Raudenbush and Bryk (1994), Kreeft and De Leeuw (1998), Snijders and Bosker (1999) and Heck and Thomas (2000) for more detailed information about the technique.

6.4.2 The use of the computer package MlwiN

MLwiN 1.10 was the computer package used in this analysis. It was developed by the Multilevel project at the Institute of Education, University of London specifically for fitting multilevel models. It can analyse data up to 15 levels and various crossed and nested structures (Kreft & De Leeuw, 1998). One of the important features of this package is the use of graphical interfaces, which allow the user to set up, fit and manipulate the models more easily than previous command driven programmes. The programme is accessible to many as it only requires Windows 95/98/NT/2000 with 32 MB RAM (Institute of Education, 2000).

Using this software, the effects on the mathematics achievement score of the school level factors and the student level factors can be analysed simultaneously as well as the interaction effects between these two levels (e.g. an example being the interaction effect of the relationship of the language spoken in class on the students' own language proficiency in the same language) on the mathematics achievement score.

6.4.3 Procedures for using MLwiN

Specifying the model

In multi-level analysis, multiple regression models are applied that assume that the data comprises a hierarchical structure, meaning that where a single dependent variable (mathematics score) is measured at the lowest level (student level), the explanatory factors or explanatory and/or independent variables (such as age of student or gender of teacher) exist at all levels (e.g. in this study the student-level and the school/classroom-level). An equation is written specifying which variables must be included when building the model.

The programme uses a set of equations (similar to regression equations) to specify which variables must be included in the model. For instance, achievement in mathematics may be influenced by language proficiency, SES and education level of the teacher. The equation for this would be:

$MATHTEST_{ij} = ß_0 + ß_1(lang)_{ij} + ß_2(SES)_{ij} + ß_3(teduc)_{ij} + R_{ij}$

where:

$MATHTEST_{ij}$ = the outcome variable (mathematics score) for student i school j

$ß_0$ = the intercept (the point at which the regression line crosses/intercepts)[1]

$ß_1$ = the regression slope associated with language proficiency (lang)

$ß_2$ = the regression slope associated with SES

$ß_3$ = the regression slope associated with teachers' education level (teduc)

R_{ij} = the random error (random variation or unreliability)

See Goldstein (1987, p. 10-14) for more information on specifying models for MLN.

Procedures for MLwiN

All the variables (student, class and school) that were hypothesised to have direct effects on achievement (on the basis of the PLS results) at the student level and the school level were combined into one dataset in SPSS. As with PLS, MLwiN does not tolerate missing values and therefore it was important that there were none in this final dataset. This data was also weighted using TOTWGT, which had been provided by the IEA's Data Processing Centre. The weights were calculated using the information from South Africa's sampling frame.

Once the dataset was finalised, the first step in the procedures was to run a *null model,* that is an empty model that contains only the dependent variable (the

[1] The intercept is the expected value of the dependent variables when the value of t independent variable is zero (Vogt, 1999).

mathematics score) and without any student level or school level variables. This is to estimate the total variance in data that has to be explained, namely the variance in the mathematics score.

Once the null model had been ascertained, then the null model plus one predictor was run to examine the deviation produced by each model which provides the researcher with an empirical basis on which to decide on the order for entering the variables into the model. After the deviation has been examined, all variables are ranked in order of largest to smallest in deviation and then can be entered in that order into the model. The individual variables are entered into model using the step up method (enter one variable at a time building up an equation and deleting non significant variables along the way). This is done to investigate which factors have significant effects on mathematics score. Then the full model is run when all student level and school level variables have been entered into the model.

The model is assessed during this process by the amount of *convergence* (the ability of the model to meet a unique solution) that occurs. Tests of significance are provided which indicate the variance involved in estimation of each parameter. In this study, the 5% level of significance was used in the statistical significance tests.

There is no hypothesised model for this analysis (as there was for the PLS analysis) but an initial or Null model was generated based on the results of the PLS analysis. The results from the combined school-level model and the student-level model were used to define the initial model, which was then analysed using MLwiN.

6.4.4 Interpretation of MLwiN results

MlwiN produces a variety of outputs. Firstly there are the *variance components,* which explain the total amount of variance that has to be explained as well as the total variance that is explained at each level (i.e.: at student or at school level). Then there is information on the *fixed effects,* which is provided in the form of gamma coefficients (which are standardised path coefficients), a standard error for each path coefficient, the t-ratio (which indicates the significance of each path coefficient) and finally the p-value (which indicates the probability estimates). In her thesis, Lietz (1995) determined the significance levels of her results when the t-ratio was below 2.00 and the p-value of larger than .05 threshold.

Outputs also include information on the *deviance* of the model. This measure indicates the goodness of fit of the model meaning: the smaller the value, the better the fit of the model to the data.

CHAPTER 7
Results of the descriptive analysis

South African pupils performed poorly in the international mathematics test. Boys and girls performed equally poorly and the South African pupils were also older than those of other countries included in the study. More than 70% of the pupils wrote in a second language, which may have had an impact on the results. A descriptive analysis of these and other variables considered as potential factors (based on the literature, the conceptual framework and restricted by the questions available in TIMSS-R) explaining the achievement of South African pupils in mathematics is an important part of the research process. The descriptive analysis provides an insight into the variables used in the modelling (see chapters 8 and 9) and provides the necessary background information and rationale for selecting them for the PLS and MLN analysis.

In this chapter, the achievement results for South African pupils are described and the background data from the pupils', mathematics teachers and school principals' questionnaires are presented and discussed. These results are an essential part of the preparation of the secondary analysis and are the starting point for the process of selecting variables for inclusion in the modelling presented in chapters 8 and 9. The results presented in this chapter are largely drawn from the national report (see Howie, 2001) and the international report (Mullis et al, 2000). Where possible the standard errors have been taken from the international report, which were generated using the Westat software WesVar. Where this was not possible, the standard error was generated using SPSS, which does not take into consideration the two-level cluster sampling of TIMSS-R and therefore may tend to underestimate the differences existing. Occasionally, the international TIMSS almanacs are referred to where no standard errors (SE) were given. Where these are used, reference is made under the table. In several tables, the achievement data is also included but no relationships are tested here and only limited attention is given to the relationships as this is done extensively in chapters 8 and 9 using Partial Least Squares analysis and multi-level analysis.

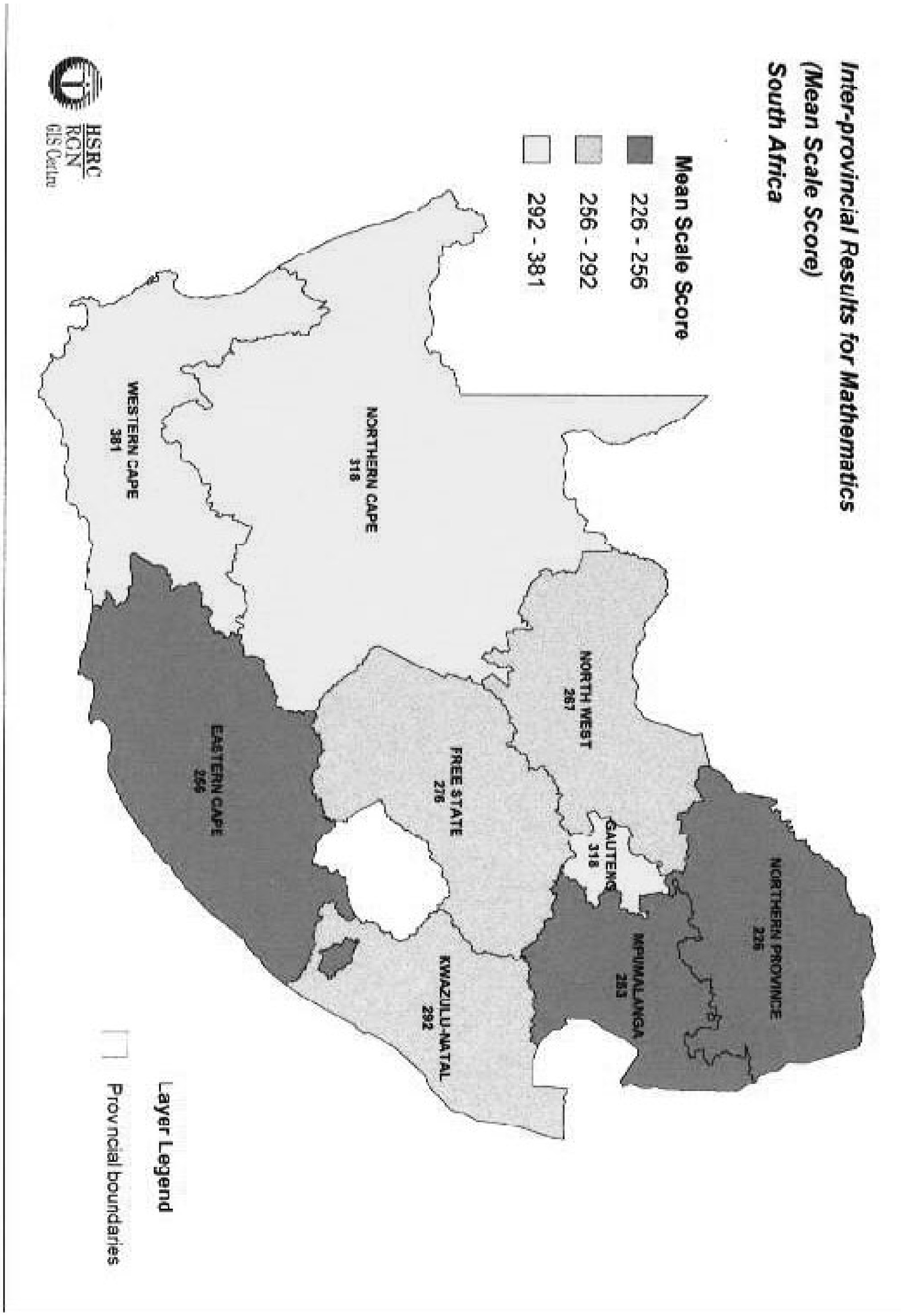
Firstly, the mathematics achievement results are described in 7.1. Then in 7.2 the results of the pupils' English achievement results are presented. The background data related to the pupils are discussed in 7.3 and that pertaining to mathematics teachers in 7.4. Finally, the findings from the school principals' data are given in 7.5 with concluding remarks being made in 7.6.

7.1 MATHEMATICS ACHIEVEMENT

In response to the first research question *"how did South African pupils perform in the TIMSS-R mathematics test?"*, the performance of the South African pupils is presented in this section. Firstly, the overall (including those by gender) and provincial results are presented in 7.1.1. Thereafter the South African results are compared with the international results in 7.1.2 and with the previous study's (1995) results in 7.1.3. Special attention is given in 7.1.4 to pupils from different languages groups with regard to their mathematics achievement.

7.1.1 South African pupils' performance in the TIMSS-R mathematics test

Exhibit 7.1
Interprovincial results for mathematics



Overall, SA pupils achieved a low score of 275 points out of 800 points for the TIMSS-R mathematics test. The province with the highest average scale score for mathematics was Western Cape with 381 scale points, but this was still significantly below the international mean score of 487. Northern Cape and Gauteng achieved the next highest scores with 318. Limpopo was below all the other provinces with a score of 226.

Table 7.1
Mean scores for South African pupils for mathematics across the nine provinces

Province	**Number of pupils**	**Mean Scale Score**	**Standard Error**	**Minimum score**	**Maximum score**
1 Eastern Cape	932	256	11.8	15	594
2 Free State	901	276	20.3	5	574
3 Gauteng	605	318	22.7	51	647
4 KwaZulu-Natal	1228	292	17.3	5	612
5 Mpumalanga	963	253	15.2	5	601
6 North West	690	267	13.6	18	594
7 Northern Cape	728	318	11.8	52	608
8 Limpopo	1166	226	4.7	6.5	458
9 Western Cape	933	381	20.7	78	699
South Africa	8146	275	6.8	5	699

Source: Howie, 2001.

The gender difference in the South African results was not statistically significant – the girls' scale score was 267 (SE 7.5) compared to the boys scale score of 283 (SE 7.3) resulting in a difference of 16 points. However, only in Western Cape were the girls' scores better in mathematics than the boys. Provinces where relatively large (but not significant) differences appear and where the boys perform on average 4-5% higher on the achievement test than the girls are Free State (34 points) and Mpumalanga (38 points).

In Table 7.2, the results for schools where English is the language of learning are compared to those where Afrikaans is the language of learning

Table 7.2
Pupils' mean mathematics scores at schools where English or Afrikaans is the language of learning in the classes tested

Language of learning	N	Mean	SE	Min	Max
Afrikaans	1 361	376	2.9	71	699
English	6 785	260	1.2	5	647
South African pupils' score	8 147	275	6.8	5	699

Source: South African TIMSS-R dataset.

There is a substantial difference in the scores of the two groups (116 points). Whilst most of the pupils that wrote the test in Afrikaans would probably speak that language at home, the same cannot be said for the English group. Most of the pupils who spoke an African language at home would attend schools where English is the language of learning. Therefore, a significant number of this second group would be learning in a second language. The native English speakers were a small group in the TIMSS-R sample (see Table 7.8).

The results of pupils' scores are given in Table 7.3 with reference to the regularity with which the language of the test is spoken at home as this is believed to have an influence on the overall results. The scores appear to reveal a trend that pupils that speak the language of the test more frequently also attain higher scores on the mathematics test. When comparing those pupils that almost always or always speak the language of the test to those that never speak the language of the test, the former achieve scores that are more than 140 points higher than the latter. Further exploration is conducted in the study (in chapter 8) to separate the confounding variable Socio-economic Status (SES) from language in explaining achievement.

Table 7.3
Mean mathematics scores for pupils who always or almost always, sometimes or never speak the language of the test at home

		Always/almost always			Sometimes			Never		
	N	*% of pupils*	*Mean*	*SE*	*% of pupils*	*Mean*	*SE*	*% of pupils*	*Mean*	*SE*
South African pupils' score	8146	23	370	2.2	53	259	1.6	24	224	1.8

Source: Mullis et al, 2000.

Whereas the comparison of South African pupils with those of other countries is discussed more extensively in 7.1.2, a few international comparative observations with respect to the 'language of the test at home' will be discussed briefly in this section.

From a comparative analysis of South African pupils' results with other countries in TIMSS-R (see Howie, 2001), some interesting observations were made. More than 70% of pupils from South Africa, Indonesia, Morocco, Philippines and Singapore did not always speak the language of the test at home. Nonetheless, the mean achievement scores vary considerably across this group of countries and there are also some interesting trends in the data. Pupils in Malaysia generally did considerably better in mathematics than those from Indonesia. Nonetheless, there is a similar trend in both countries where pupils who never speak the language of the test at home, namely 9% in Indonesia and 10% in Malaysia, still appeared to outperform those who always or sometimes spoke the language of the test at home. It suggests therefore that the differences between language groups are not only dependent on language. Indonesia for instance is described as a highly diverse country with more than 600 languages and 200 million people (Baker and Prys-Jones, 1998, p. 375) and yet apparently their pupils do not appear to have been disadvantaged by writing the test in a second language. A similar pattern was also observed for Morocco and the Philippines in mathematics. In Singapore there does appear to be a difference, but yet those who never speak the language of the test at home, still outperform pupils from 33 other countries.

Even looking at the other African countries, the scores of those never speaking the language at home are better in the case of Morocco for mathematics and are comparable for those from Tunisia. This issue needs to be explored further as it appears from the data, that the pupils from other developing countries do not seem to be disadvantaged by writing tests in their second or third language in mathematics or science, however it is not clear why this is. Important lessons may lie in the answers for South Africa.

Due to the influence of the political context on education, data on race were also collected. In South Africa, the political (as well as social) history had a profoundly negative effect on the education system as a whole. This can still be measured according to the classifications used for the segregation of schools along racial lines. It was anticipated in advance that the results would reveal the depth of the inequalities of the past and that these would also correlate with socio-economic data that had also been collected regarding the pupils' background. Therefore, it is no surprise to discover that the "white pupils" (the previously advantaged group of European descent) scores are substantially higher than those of other groups (see Table 7.4) and that of the groups the most disadvantaged group previously (African) would attain the lowest scores. However, what is worth noting is that despite being considered the most advantaged group (and about 100 points above the national mean score), the white pupils' mean score was nonetheless more than 100 points below the international mean score.

Table 7.4
Mean mathematics scores of African, coloured, Indian and white pupils

Race group	N	Mean score	SE	Min	Max
African	5412	254	1.2	5	647
Asian	76	269	13.8	7	589
Coloured	1172	339	2.9	34	608
Indian	199	341	8.6	12	612
white	831	373	4.9	18	699
South African pupils' mean score	8 147*	275	6.8		
International mean score	–	487	0.7		

Note: * overall results from Mullis et al, 2000.
Source: South African national dataset.

South African pupils' performance was relatively low in every mathematics content area (see Table 7.5) compared to all the participating countries. For South Africa, the average score for data representation, analysis and probability is the highest score of 356 points relative to the international average. Ironically, this is also the area not included in the intended curriculum at Grade 8 level. The lowest achievement relative to the international average is in the area of algebra with a score of 293.

Table 7.5
Mean scores per mathematics topic

	Fractions and number sense		Measurement		Data representation, analysis and probability		Geometry		Algebra	
Content area	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
SA mean score	300	6.0	329	4.8	356	3.8	335	6.6	293	7.7
Int. mean score	487	0.7	487	0.7	487	0.7	487	0.7	487	0.7

Source: Mullis et al, 2000.

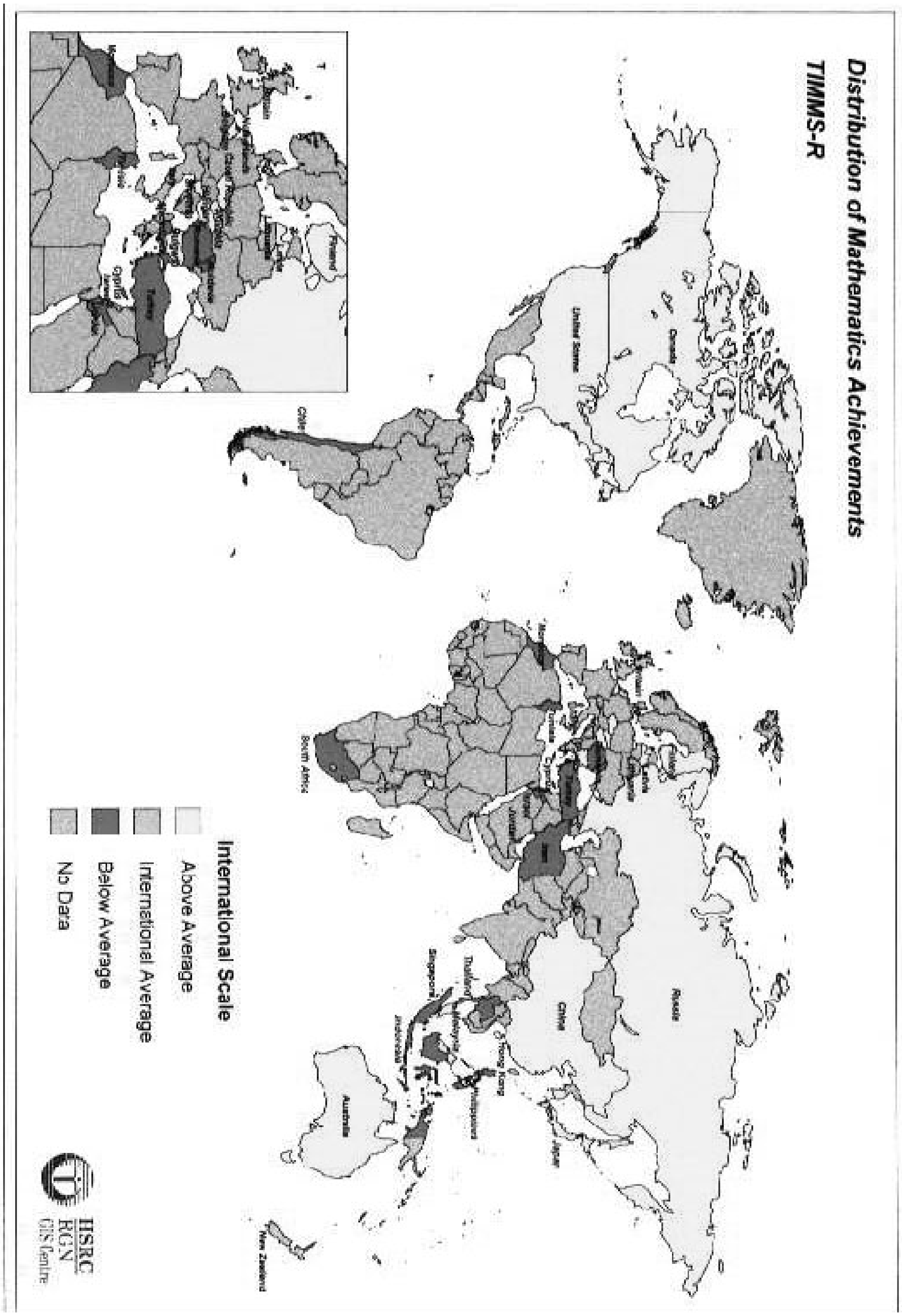
A more detailed analysis (Howie, 2001) shows that pupils have trouble with the interpretation of tables, figures and illustrations. They struggle with complex questions requiring more than one step and appear unable to express themselves in writing. Difficulties were noted where pupils were required to comprehend word problems and to articulate and solve problems in writing. Pupils also had considerable difficulty dealing with fractions and with geometry questions regarding calculating "area". In general, when faced with multiple-choice questions pupils resorted to guessing the answer and in some cases were successfully distracted by questions testing misconceptions. Pupils on the whole were unable to communicate their answers in the language of the test and they lacked the basic mathematics knowledge expected at the Grade 8 level. Similar findings were noted in the analysis of the TIMSS 1995 items (see Howie & Plomp, 2001).

This is a further motivating factor to explore the language proficiency of the pupils in greater depth as well as a more detailed investigation of selected mathematics items with regard to language issues.

7.1.2 The performance of the South African pupils compared with pupils from other countries

In response to the second research *question "how does the performance of South African pupils compare to pupils of other countries?*", South African pupils performed poorly when compared to other participating countries attaining an average score well below that of the international average.

Exhibit 7.2
Distribution of Mathematics Achievement



The South African mean score of 275 (standard error (SE) 6.8) is well below the international mean of 487 (SE 0.7) (see Figure 7.1). The result is significantly below the mean scores of all other participating countries, including the two other African countries of Morocco and Tunisia as well as that of other developing or newly developed countries such as Malaysia, the Philippines, Indonesia and Chile. As in 1995, pupils from the Asian countries of Singapore (at the top with 604 scale points), Korea, Chinese Taipei, Hong Kong and Japan demonstrated the highest levels of achievement in mathematics.

As can be seen in Figure 7.1, only the most proficient pupils in South Africa (and incidentally the same holds for Chile, Morocco and the Philippines) attained the level of the average pupils from Singapore. South African pupils scoring around the country's mean score fell below the least proficient pupils from almost all other countries with the exception of Morocco, the Philippines, Chile and Indonesia.

Virtually all the pupils participating in TIMSS-R had had 8 years of formal schooling. There were a few exceptions, for example, some of the Australian pupils had received 9 years of formal education, as had all the English pupils. This is a consequence of entering school at the age of five. Pupils from Finland and the Philippines had received only 7 years of schooling.

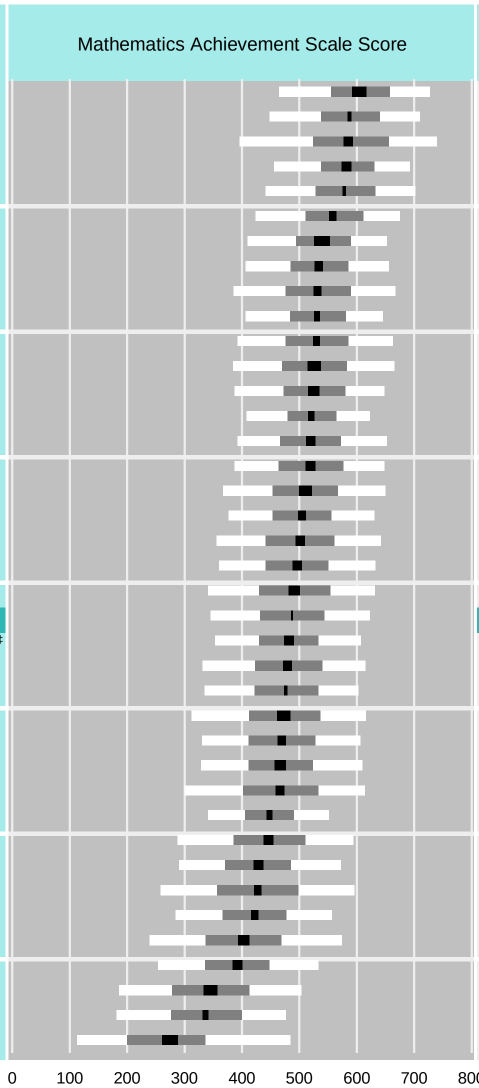
South African pupils, on average, were the oldest pupils in TIMSS-R as they were 15.5 years of age. This was significantly above the international average age of 14.4 years. However, South African pupils enter school at the age of seven years[1] in contrast to the other countries where the entrance age is five or six years. The only other country where the average age was above 15 years was Lithuania (15.2).

The poor performance of South African pupils can also be illustrated when one looks at some benchmark data.
The **International Top 10%** benchmark that is, the average score achieved by the top 10% of pupils internationally, corresponds to a score of 616 out of 800. Very few South African pupils (less than 0.5%) reached this benchmark, in contrast to Singapore where 46% of their pupils did.

[1] In 2001, a landmark court case was won by parents (against the Minister of Education) who wanted their children to enter government schools before the age of seven years. As from 2002, parents will be allowed to send their children to government schools at the age of six if considered school-ready.

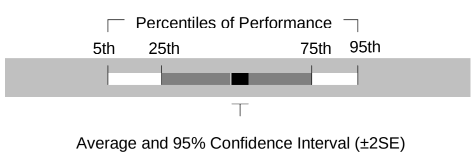
Distribution of Mathematics Achievement

TIMSS 1999 8th Grade Mathematics



Country	Average Scale Score	Years of Formal Schooling	Average Age
Singapore	s 604 (6.3)	8	14.4
Korea, Rep. of	s 587 (2.0)	8	14.4
Chinese Taipei	s 585 (4.0)	8	14.2
Hong Kong, SAR †	s 582 (4.3)	8	14.2
Japan	s 579 (1.7)	8	14.4
Belgium (Flemish) †	s 558 (3.3)	8	14.1
Netherlands †	s 540 (7.1)	8	14.2
Slovak Republic	s 534 (4.0)	8	14.3
Hungary	s 532 (3.7)	8	14.4
Canada	s 531 (2.5)	8	14.0
Slovenia	s 530 (2.8)	8	14.8
Russian Federation	s 526 (5.9)	7 or 8	14.1
Australia	s 525 (4.8)	8 or 9	14.3
Finland	s 520 (2.7)	7	13.8
Czech Republic	s 520 (4.2)	9	14.4
Malaysia	s 519 (4.4)	8	14.4
Bulgaria	s 511 (5.8)	8	14.8
Latvia (LSS) [1]	s 505 (3.4)	8	14.5
United States	s 502 (4.0)	8	14.2
England †	l 496 (4.1)	9	14.2
New Zealand	l 491 (5.2)	8.5 to 9.5	14.0
International Avg.	487 (0.7)		14.4
Lithuania [1‡]	l 482 (4.3)	8.5	15.2
Italy	l 479 (3.8)	8	14.0
Cyprus	t 476 (1.8)	8	13.8
Romania	l 472 (5.8)	8	14.8
Moldova	t 469 (3.9)	9	14.4
Thailand	t 467 (5.1)	8	14.5
Israel [2]	t 466 (3.9)	8	14.1
Tunisia	t 448 (2.4)	8	14.8
Macedonia, Rep. of	t 447 (4.2)	8	14.6
Turkey	t 429 (4.3)	8	14.2
Jordan	t 428 (3.6)	8	14.0
Iran, Islamic Rep.	t 422 (3.4)	8	14.6
Indonesia	t 403 (4.9)	8	14.6
Chile	t 392 (4.4)	8	14.4
Philippines	t 345 (6.0)	7	14.1
Morocco	t 337 (2.6)	7	14.2
South Africa	t 275 (6.8)	8	15.5

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1998-1999.



▲ Country average significantly higher than international average

● No statistically significant difference between country average and international average

▼ Country average significantly lower than international average

Significance tests adjusted for multiple comparisons

† Met guidelines for sample participation rates only after replacement schools were included.
[1] National Desired Population does not cover all of International Desired Population. Because coverage falls below 65%, Latvia is annotated LSS for
[2] National Defined Population covers less than 90 percent of National Desired Population.
‡ Lithuania tested the same cohort of students as other countries, but later in 1999, at the beginning of the next school year.
( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Figure 7.1
International mean scores of TIMSS-R participating countries

Only 1% of South African pupils reached the **International Upper Quarter** benchmark, the average score achieved by the top 25% of pupils internationally, which corresponds to a score of 555 (68% of the possible 800) points. This is a great contrast to the Asian countries where the benchmark was reached by more than 60% of pupils from Japan, Hong Kong, Korea and Chinese Taipei and 75% of Singapore pupils. The top 25% of South Africa's pupils achieved 337 out of 800 (42%).

Overall, the South African results appear very low in comparison to all the other countries participating in TIMSS-R, including the other two African countries, Tunisia and Morocco.

Of the newly developed or developing countries in Table 7.6, Malaysia attained significantly higher results than the other countries. Perhaps this may have resulted from the vigorous campaign over the past decade to improve their science and mathematics education. None of the countries listed below were found to have significant gender differences, with the exception of Tunisia where boys obtained significantly higher scores (25 points (SE 2.2) than girls.

Table 7.6
South African pupils mean scores for mathematics compared to those of selected developing countries and the international mean

	Overall score		**Boys**		**Girls**	
Countries	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
Chile	392	4.4	397	5.8	388	4.3
Indonesia	403	4.9	405	5.0	401	5.4
Jordan	428	3.6	425	5.9	431	4.7
Malaysia	519	4.4	517	6.0	521	4.7
Morocco	337	2.6	344	4.1	326	5.3
Philippines	345	6.0	337	6.5	325	6.9
Thailand	467	5.1	465	5.5	469	5.7
Tunisia	448	2.4	460	2.9	436	2.4
SA score	275	6.8	283	7.3	267	7.5
International score	487	0.7	489	0.9	485	0.9

Source: Mullis et al, 2000:32, 50.

7.1.3 The performance of the South African pupils in mathematics in 1998 compared with the performance of pupils in 1995[2]

This section addresses the research question: *"How does the performance of the South African pupils in 1998 compare with the performance of the South African pupils in 1995?"*

There were 26 countries in TIMSS-R that also participated in the original TIMSS study, including South Africa. Overall, the international average achievement in mathematics did not change, as there is only a small increase by 2 scale points (from 519 in 1995 to 521 in 1999 across the 26 countries).

As can be seen in Figure 7.2, South Africa's overall score decreased by 3 scale points, which was not statistically significant. In other words, there is no real difference in performance between the pupils in 1999 and those in 1995.

The difference in achievement between 1995 and 1999 for the **top 10%** was minimal and not statistically significant for any country including South Africa. Less than 0.5% of pupils in South Africa reached the top 10% in both 1995 and 1999. South Africa was the only country where this happened in both years.

Internationally, there were no significant differences in achievement for mathematics for either girls or boys between 1995 and 1999. On average, girls performed 3 points better than in 1995 and boys achieved 2 points more. In South Africa there was an increase in the score for girls (from 264 in 1995 to 267 in 1999). There was a decrease in the score for boys, who on average scored 10 points less in 1999 (from 293 in 1995 to 283 in 1999). Neither of these results is statistically significant.

In terms of gender differences between girls and boys, there were significant differences in some countries in 1999, as in 1995. An important finding, however, is that fewer countries had these differences (3 compared to 6) in 1999. In 1995, the Czech Republic, Iran, Japan, Korea, the Netherlands and Israel all had significant differences in achievement that favoured the boys. In 1999, only three countries still have these significant differences favouring boys; the gap has decreased in others.

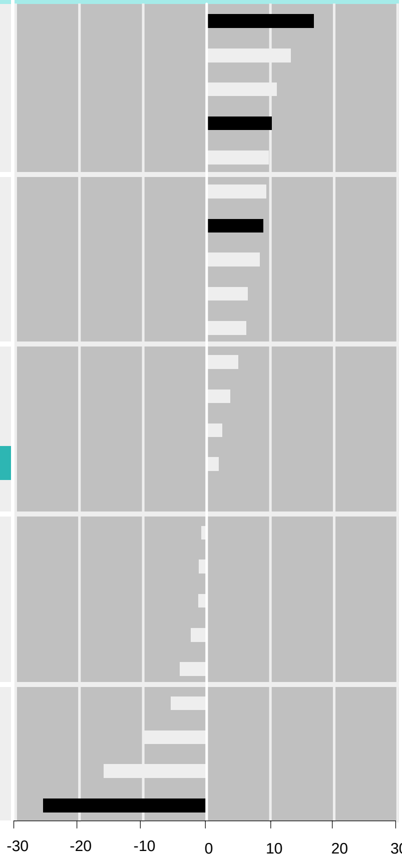
[2] *Note*: TIMSS used Item Response Theory methods to place the eighth grade results from 1995 and 1999 on the same scale. See Appendix A of Mullis et al. (2000) for more details.

Trends in Mathematics Achievement

TIMSS 1999 8th grade Mathematics

	1995 Average Scale Score	1999 Average Scale Score	1995-1999 Difference
Latvia (LSS)	488 (3.6)	505 (3.4)	17 (5.0)
Hong Kong, SAR	569 (6.1)	582 (4.3)	13 (7.5)
Netherlands	529 (6.1)	540 (7.1)	11 (9.5)
Canada	521 (2.2)	531 (2.5)	10 (3.2)
Lithuania	472 (4.1)	482 (4.3)	10 (6.1)
United States	492 (4.7)	502 (4.0)	9 (6.2)
Cyprus	468 (2.2)	476 (1.8)	9 (2.9)
Belgium (Flemish)	550 (5.9)	558 (3.3)	8 (6.8)
Korea, Rep. of	581 (2.0)	587 (2.0)	6 (2.8)
Australia	519 (3.8)	525 (4.8)	6 (6.1)
Hungary	527 (3.2)	532 (3.7)	5 (4.9)
Iran, Islamic Rep.	418 (3.9)	422 (3.4)	4 (5.2)
Russian Federation	524 (5.3)	526 (5.9)	2 (8.0)
International Avg. §	519 (0.9)	521 (0.9)	2 (1.3)
Slovak Republic	534 (3.1)	534 (4.0)	0 (4.9)
Slovenia	531 (2.8)	530 (2.8)	-1 (3.9)
Romania	474 (4.6)	472 (5.8)	-1 (7.4)
England	498 (3.0)	496 (4.1)	-1 (5.2)
Japan	581 (1.6)	579 (1.7)	-2 (2.2)
Singapore	609 (4.0)	604 (6.3)	-4 (7.4)
Italy	491 (3.4)	485 (4.8)	-6 (6.0)
New Zealand	501 (4.7)	491 (5.2)	-10 (7.1)
Bulgaria	527 (5.8)	511 (5.8)	-16 (8.2)
Czech Republic	546 (4.5)	520 (4.2)	-26 (6.1)

Difference in Average Achievement Between 1995 and 1999



SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1998-1999.

Countries with Unapproved Sampling Procedures at the Classroom Level in 1995

	1995 Average Scale Score	1999 Average Scale Score	1995-1999 Difference
Israel	513 (6.2)	482 (4.7)	-32 (7.8)
South Africa	278 (9.2)	275 (6.8)	-3 (11.5)
Thailand	516 (6.0)	467 (5.1)	-49 (7.9)

Difference statistically significant ■

Difference not statistically significant □

Significance tests adjusted for multiple comparisons

§ International average is for countries that participated and met sampling guidelines in both 1995 and 1999.

Trend notes: Because coverage fell below 65% in 1995 and 1999, Latvia is annotated LSS for Latvian-Speaking Schools only. Lithuania tested later in 1999 than in 1995, at the beginning of the next school year. In 1995, Italy and Israel were unable to cover their International Desired Population; 1999 data are based on their comparable populations.

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

Figure 7.2

International trends in TIMSS mean scores 1995-1999

There were no significant differences found in 1995 or in 1999 between South African boys and girls. Although in 1995, there was a 29-point difference between girls and boys, this gap has narrowed to a 16-point difference in 1999.

The trend data reveal very few changes among the content areas in mathematics, as changes on this level are difficult to effect and take a number of years to manifest themselves. Perhaps TIMSS 2003 will be able to show more differences in achievement on this level.

Overall, differences in the percent correct on country level were found for five countries, three of which were positive increases in achievement. The only significant difference in achievement (between 1995 and 1999) internationally in specific content areas was found in data representation, analysis and probability. The average percent correct of South African pupils decreased by 2% for fractions and number sense, measurement and data representation, analysis and probability, and 1% for geometry and algebra, none of which was significant.

7.1.4 How did pupils from different language groups perform in the mathematics test?

As part of the exploration into the effect of language on mathematics achievement, the scores of pupils whose main language was an African language was compared to those whose main language was English or Afrikaans. The results are presented in Table 7.7.

Table 7.7
Mean scores of pupils with one of the African languages or Afrikaans, or English as their main language

	Mathematics				
Main language at home	*N*	*Mean*	*SE*	*Min*	*Max*
African languages	5496	251	1.1	5	647
Afrikaans	1 281	375	3.1	16	698
English	533	374	5.2	55	632
Other languages	24	352	21.6	135	569
South African Mean score	8 147	275	6.8		
International mean score		487	0.7		

Note: SA and international scores from Mullis et al, 2000.
Source: South African national dataset.

Pupils who spoke either English or Afrikaans at home achieved higher scores than those who did not and 100 points above the national average. What is illuminating is that children that spoke other languages at home (for example, Greek, Portuguese or Tamil) and therefore also learned in a second language, they scored only 20 points on average less than first language speakers. However, children speaking African languages at home attained 100 points less than the other group of second language speakers. No group of pupils came close to attaining the international average for mathematics

7.2 ENGLISH ACHIEVEMENT

In addition to the mathematics and science tests conducted in TIMSS-R, an English language proficiency test was included that aimed to assess pupils' writing related skills and language usage in English. The test comprised 40 items, which were multiple-choice items. Thirty of the forty items had four options, whilst the remaining 10 items had two answer options. A copy of the test can be found in Appendix 2, whilst a discussion of its contents may be found in chapter 5.

7.2.1 How did pupils perform in the English language proficiency test?

This section addresses research question 7, namely, "*How did pupils perform in the English Language proficiency test?*" The overall mean score for the language test was 17 out of 40 (n= 8349). The minimum score attained was 0 and the maximum score 40. In general, the scores for boys and girls were comparable.

Table 7.8
Overall mean score for the English language proficiency test for girls and boys

	Girls *N = 4 230*		**Boys** *N = 3 795*	
	Mean	*SE*	*Mean*	*SE*
Mean score	17.26	0.1	16.84	0.1

The scores varied across the nine provinces (see Table 7.9) with the wealthiest and most urbanised provinces (Gauteng and Western Cape) attaining the highest overall scores. Thereafter, pupils in the Northern Cape achieved the highest of the remaining seven provinces. This is also consistent with the finding that Afrikaans speaking pupils performed reasonably well on the test as the majority of the Northern Cape pupils tested were Afrikaans speaking. Of some concern is the very low proficiency in English displayed by the Northern Province pupils which was evident from the lowest scores attained of any province. In contrast to other provinces where the maximum score found was 34 points or higher, the maximum score recorded was 27 points out of 40.

Table 7.9
Mean English language proficiency scores attained by pupils across the nine provinces

Province	N	Mean score	SE	Min	Max
Eastern Cape	934	15.48	0.2	0	38
Free State	965	16.99	0.2	3	36
Gauteng	643	20.86	0.3	0	40
Kwa-Zulu Natal	1 229	16.46	0.2	0	39
Mpumalanga	1 011	15.64	0.2	0	38
North-West	696	15.93	0.2	4	34
Northern Cape	730	18.33	0.2	0	37
Limpopo	1 176	13.80	0.1	4	27
Western Cape	965	21.96	0.2	0	40
South Africa	8 145	17.01	0.7	0	40

Source: South African National Dataset.

A great variation across the items can be seen in Table 7.10. Higher percentages of pupils answered correctly for items with only two options as guessing presumably resulted in more correct answers. However, more than 50% of the pupils answered items 25, 26, 28, 29 and 30 correctly, which had four options. The first two items dealt with prepositions, the next two with syntaxes and the last item dealt with converting a verb to a noun.

Pupils had particular problems with item 16 (19% of pupils answered correctly) where the language requirement was sequencing and the concord of sentences.

Table 7.10
Percentage of pupils answering items on the English language proficiency test correctly

Item number	% of pupils answering correctly	Item number	% of pupils answering correctly
1	41.0	21	32.9
2	34.3	22	44.1
3	29.5	23	26.4
4	36.5	24	38.2
5	35.2	25	55.0
6	35.6	26	70.4
7	29.8	27	28.1
8	48.8	28	80.3
9	42.6	29	69.9
10	35.3	30	58.3
11	26.1	31	58.6
12	41.3	32	66.5
13	41.8	33	70.2
14	36.4	34	69.0
15	31.9	35	69.8
16	19.4	36	50.7
17	29.8	37	50.8
18	32.0	38	74.0
19	40.2	39	51.4
20	33.3	40	54.5

Note: Numbers in italics indicate questions with two options.
Source: South Africa National dataset.

As the test was designed for English second language speakers, it is not surprising that native English speakers performed the best of all language groups (see Table 7.11), although one might have expected the scores to have been higher given this fact. The Afrikaans speaking children attained the next highest score with 21 points out of 40. The scores were more or less consistent across the pupils whose main language was an African language. The Tswana and Southern-Sotho speaking pupils attained the highest scores out of those speaking African languages. This may reflect the urbanisation of the people speaking these two languages although other interpretations for this may also exist, for instance the emphasis on English language and communication skills in the former Bophutatswana, where most of the Tswana-speakers originate.

Table 7.11
Pupils' English test mean score as per pupils' main language

Main language	Score	
	Mean	*Std Deviation*
Afrikaans	21.46	7.0
English	25.03	8.7
Ndebele	14.89	4.0
N.Sotho	14.32	4.0
S.Sotho	15.95	5.6
Swazi	14.82	5.1
Tswana	16.16	5.6
Venda	14.25	4.2
Xhosa	15.47	5.1
Zulu	15.01	4.7

Source: South African National dataset.

When one compares the pupils who speak African languages, English, Afrikaans or other languages at home (in Table 7.12) there are also some noticeable differences. Not surprisingly, native English-speakers achieved the highest scores, however the mean score is not that high considering that they were writing second-language test. Pupils from the African language group clearly struggled with the test and the low average score reflects that. The other second language groups (Afrikaans and other languages) performed relatively well in comparison with the English group.

Table 7.12
Pupils' English test mean score as per language group

Language groups	N	English scores			
		Mean	*SE*	*Min*	*Max*
African languages	5 496	15	6.5	0	36
Afrikaans	1 281	21	0.2	4	39
English	533	25	0.4	0	40
Other languages	24	21	1.6	9	36

Source: South African National dataset.

Another comparison can also be made between those who always spoke the language of the test at home (thus combining the English and Afrikaans speaking pupils) compared to those who sometimes and those who never spoke the language of the test at home. From Table 7.13, it would appear that the more frequently the pupils spoke the language of that the mathematics test was written in at home (i.e. English or Afrikaans) the better the English. Clearly the fact that some pupils never have the opportunity to speak English at home has a negative impact on their proficiency in that language.

Table 7.13
Pupils' English test mean score as per who always or almost always, sometimes or never speak the English or Afrikaans at home

	Always or almost always		Sometimes		Never	
	Mean	*SE*	*Mean*	*SE*	*Mean*	*SE*
Mean score	21.30	0.2	16.30	8.2	14.09	9.3

Source: South African national dataset.

It was interesting to see that amongst children that never spoke English or Afrikaans at home, the highest score on the English test obtained was 36; amongst those who sometimes spoke the language the highest score was 38 and only amongst those who always or almost always spoke the language of the test, the maximum score of 40 was attained.

7.2.2 The exposure to English of pupils who do not have English as a main language

This section addresses the research question *"What exposure to English do pupils who do not have English as a main language have?"* As it was anticipated that the majority of pupils would not have English as a main language, questions were included in the questionnaire to measure the extent to which those pupils are exposed to English on a daily basis. It was anticipated that these were possible factors related to language that might be included in explaining achievement.

Television

Pupils were asked about which of the available television stations they watched (see Table 7.14). These stations were then classified into predominantly English or predominantly African stations and another option was included "don't watch TV". An analysis of this data revealed that just over half the pupils watched stations where the African languages were dominant than the others. Thirty-one percent watched predominantly English channels.

Table 7.14
Language of preferred television channels

	N	Predominantly English channels	Predominantly African languages channels	Don't watch TV
% of pupils	7 445	30.8	51.8	17.4

Source: South African National dataset.

Radio

Pupils were also asked to specify which language (of all 11 languages) was most dominant on the radio station they most frequently listened to and the results are listed in Table 7.15. On average 66% of the pupils listened to radio stations where African languages were most prominent. Although 26% of pupils listened to English stations, only 7.2% of the pupils had English as their main language. An interesting finding though is that the opposite is true for Afrikaans. A total of 8.5% of the pupils listen to Afrikaans radio stations, although more than double that percentage (17.8%) has Afrikaans as a main language. One possible explanation is that Afrikaans stations may be considered conservative and aim at a more mature audience and therefore are less appealing to this age group whilst English stations often appeal to the popular culture which is more attractive to this age group.

In general, there seems to be a link between pupils speaking African languages at home with their preferred choice of radio station, with possible exceptions of Xhosa and Zulu speaking pupils. A possible explanation for these two groups is that large numbers of these cultural groups may be found in Gauteng and Western Cape which are more urbanised and where English stations proliferate.

Table 7.15
Language of pupils' most preferred radio station

		% of pupils											
	N	*Afrikaans*	*English*	*Ndebele*	*North Sotho*	*South Sotho*	*Swazi*	*Tsonga*	*Tswana*	*Venda*	*Xhosa*	*Zulu*	*Other*
Language – radio station	7 645	8.5	25.7	3.3	7.7	7.5	3.5	1.2	10.0	3.6	13.1	15.4	0.4
Home language	7 520	17.9	7.2	2.2	9.1	8.8	3.9	1.4	10.8	3.7	15.8	19.0	0.4

Source: South African National dataset.

Language used in the classroom

Whilst at the time of the study, English and Afrikaans were the official languages of learning in schools, there is much evidence that African languages are commonly used or that code-switching[3] takes place frequently in South African classrooms (Setati, 1999). Therefore, questions were included in both the pupils and teachers questionnaires about the frequency of that occurrence. Pupils were asked what language they used most often (on a four-point scale) to ask questions in class.

[3] Where the teachers and pupils switch between their main language and the official language of learning.

Only 53% of the pupils reported (Table 7.16) that they always used the language of the test (i.e.: the official language of learning) to ask a question in class. More than one-third of the pupils only sometimes used the official language or always used their home language.

Table 7.16
Language most commonly used by pupil to ask questions in class

	N	Always language of test	Mostly language of test	Sometimes language of test	Home language
% of pupils	7 802	53.3	11.3	23.4	12.0

Source: South African National dataset.

Pupils were also asked about the language that the teacher used to explain a new or difficult concept in class (see Table 7.17). Similar results were found to the pupils and only 52% of the teachers were in fact always using the official language in the class.

Table 7.17
Language used by mathematics teacher in class to explain new or difficult concepts in mathematics

	N	Always language of test	Mostly language of test	Sometimes language of test	Home language
% of pupils	7 846	52.4	12.3	22.8	12.5

Source: South African National dataset.

The implications arising from the results of language usage in the class are that this may either have a positive or negative effect on the pupils' academic achievement in mathematics. Many would argue that explaining new or difficult concepts in a home language would promote understanding and therefore promote learning. However, others may argue that if teachers continue with this practice, that pupils are never challenged to communicate when under pressure in the languages of learning and therefore will perform poorly in tests and examinations when this opportunity to communicate in their main language is denied.

7.3 PUPILS' BACKGROUND CHARACTERISTICS

The first of the two main research questions in the descriptive analysis was "*Who were the participants?*" In this section a profile is given of the pupils who participated in TIMSS-R, whilst in 7.4, a profile of the mathematics teachers and in 7.5, a profile of the schools that participated are provided. In this section, data on personal characteristics (age, gender and race), home background (language, parental education, SES and people in the home) and pupils' attitudes and aspirations were analysed and the findings are presented.

7.3.1 Personal characteristics

The age of the pupils ranged from 9 years to 28 years. The mean age was 15.6 years compared to the international mean of 14.3 years. The mean age of the pupils writing the Afrikaans version of the mathematics test was 14.9 years compared to 15.6 years writing the English version of the test. The youngest pupil reported was 9.4 years and the oldest was 28.8 years of age. More than half of the pupils (52.8 %) were girls and 47.2% were boys. In terms of race (see Table 7.18), 70% of the pupils that responded were African.

Table 7.18
Race of the pupils participating in TIMSS-R

	N	African	Asian	Coloured	Indian	White
% of pupils	7 887	70.1	1.0	15.0	2.5	11.4

Source: South African National dataset.

7.3.2 Home background characteristics

The most commonly spoken language of the pupils at home is Zulu (19%) (see Table 7.19) of the pupils followed by Afrikaans (17.9% of pupils). Only 7% of pupils spoke English as their first language (being only the 7th most commonly spoken out of the group of pupils tested).

Table 7.19
Language spoken most at home

	N	Afrikaans	English	Ndebele	North Sotho	South Sotho	Swazi	Tsonga	Tswana	Venda	Xhosa	Zulu	Other
% of pupils	7 520	17.9	7.2	2.2	9.1	8.8	3.9	1.4	10.8	3.7	15.8	19.0	0.4

Source: South African National dataset.

Only 23% of the pupils reported speaking the language of the mathematics test at home (see Table 7.20). The trend as indicated from the mathematics achievement scores seems to show that pupils that never speak the language of the test at home achieve lower scores than those that always do.

Table 7.20

Frequency with which pupils speak the language of the test at home and their mathematics scores

		% of pupils											
		always or almost always				sometimes				never			
	N	*Mean*	*SE*	*Score*	*SE*	*Mean*	*SE*	*Score*	*SE*	*Mean*	*SE*	*Score*	*SE*
SA pupils	8 147	23	2.2	370	11.7	53	1.6	259	4.7	24	1.8	224	9.3
Int. pupils		79	0.3	493	0.2	17	0.2	466	2.3	5	0.1	455	4.1

Source: South African National dataset.

Whilst 8.5% of the pupils writing the test in Afrikaans did not speak the language of the test as their home language, this was not the case for those writing the test in English (see Table 7.21). As many as 87.5% of the pupils writing in English, did not always speak that language at home (although 61% sometimes did). The extent to which this group was disadvantaged in writing the mathematics achievement test will be explored further.

Table 7.21

Frequency with which pupils speak the language of the test at home

Pupils write the test in	N	% of pupils		
		always or almost always	*sometimes*	*never*
Afrikaans	1 408	91.5	8.2	0.3
English	6 610	12.5	61.4	26.1

Source: South African National dataset.

Parental education

Fifteen percent of grade 8 pupils reported that either their mother or father had finished university. Parental education is often linked to pupils' achievement. It may influence the parental aspirations for the child and parents with higher levels of education may provide additional means and resources to assist their children at school as well as providing a more stimulating learning environment at home. It is therefore no surprise that pupils, whose parents have completed their own university education, have correspondingly higher results on average than others. As can be seen from the Table 7.22, pupils whose parents completed secondary school achieved considerably higher scores than those who did not finish secondary or primary school (both nationally and internationally). Twelve percent of pupils did not know the education level of their parents and this may also be deliberate by the parents who do not wish to share this with their children. However, a mixture of higher achieving and lower achieving pupils fit into this category therefore explaining the ambivalent results.

Table 7.22
Highest level of education of either parent

Level of education of either parent	South African pupils				International average			
	% of pupils	*SE*	*Score*	*SE*	*% of pupils*	*SE*	*Mean score*	*SE*
Finished university	15	1.1	323	12.9	20	0.2	525	1.4
Finished upper secondary school, not university	30	1.3	293	9.4	41	0.2	492	0.8
Finished primary, but not secondary school	32	1.1	256	6.2	21	0.2	460	1.1
Did not finish primary school	11	1.2	225	9.1	6	0.1	418	3.0
Don't know	12	0.9	266	9.7	12	0.1	463	1.3

A closer look at parental education levels separately (in Table 7.23) as well as a comparison between the groups taking the test in different languages reveals some interesting trends. A higher percentage of fathers attended and completed university than mothers. A larger percentage of mothers only attended primary school (Afrikaans group 23% and English group 32%) compared to the fathers (Afrikaans group 16% and English group 23%). Substantially more pupils did not know the education levels of the fathers than their mothers and this probably reflects the many pupils living only with the mothers.

Table 7.23
Highest level of education attained by pupils' mothers and fathers as per the language of the test

Language pupils writing the test in	N	% of pupils							
		Some primary school or no schooling	*Finished primary school*	*Some secondary school*	*Finish secondary school*	*Some vocational education*	*Some university*	*Finish University*	*Don't know*
Mother									
Afrikaans	1397	8.8	14.2	20.5	19.3	2.8	2.8	13.1	18.5
English	6666	17.2	14.6	18.4	16.3	4.4	2.6	8.1	18.5
Father									
Afrikaans	1384	5.9	9.7	1836	18.8	5.1	2.9	15.2	23.8
English	495	12.6	11.0	13.9	15.0	4.8	3.6	9.4	29.9

Source: South African National dataset.

People living in the home

Eighty-seven percent of pupils said that their mothers were living at home with them. However, only 60% said that their father was living at home, which is far below the international average of 81%. Forty-two percent had grandparents living with them and this was far more than the international average of 24%, and 43% had other relatives living with the family compared to 16% of the international average. Finally, 25% of South African pupils claim to have non-relatives living with their families. The average number of people living in the homes of the pupils was seven with a maximum of 60 being found.

Books in home

Books in the home may also be used in contexts like South Africa as an indicator of socio-economic status as well as parental education levels. As can be seen from Table 7.24, the results do show a limited trend (both nationally and internationally) in that pupils that have more than one shelf (of a book case) of books at home generally perform better in mathematics than those with very few or no books. However, the differentiation between two or more book cases is less obvious and this may be due to the fact that the pupils had to estimate the number of books in the home or alternatively, simply having access to a collection of books, i.e. that the resources are available in the home, is sufficient to make a difference. However, it is clear that a far larger percentage of South Africa pupils have access to fewer books than their peers internationally.

Table 7.24
Books in the home and Mathematics achievement

	South African pupils				**International pupils**			
Number of books in the home	*% of pupils*	*SE*	*Mean Score*	*SE*	*% of pupils*	*SE*	*Mean Score*	*SE*
None or very few (0-10)	43	1.6	248	9.6	14	0.2	443	1.6
About one shelf (11-25)	31	0.8	281	6.6	22	0.1	464	0.9
About one bookcase (26-100)	14	0.8	317	10.4	29	0.2	492	0.8
About two bookcases (101-200)	6	0.5	343	17.8	16	0.1	509	1.1
Three or more bookcases (more than 200)	7	0.5	320	16.8	18	0.2	515	1.3

Source: Mullis et al, 2000.

Far more pupils (45%) from the English group had fewer books in the home (less than 10 books) compared to the Afrikaans group (30%), as can be seen from Table

7.25. Approximately double the percentage of pupils from the Afrikaans group had more than 200 books compared to the English group.

Table 7.25
Percentage of pupils writing the test in English or Afrikaans reporting on the numbers of books in the home

% of pupils writing the test in	N	0-10	11-25	26-100	101-200	More than 200
Afrikaans	1 396	30	30	19	10	11
English	6 372	45	31	13	5	6

Source: South African national dataset.

Educational aids in the home

As can be seen from Table 7.26, very few pupils in South Africa (9%) have all three aids, namely, a dictionary, study desk and a computer compared to the international average of 41%. What is also evident is the considerable difference in the national achievement scores between those that have three aids and those that do not in mathematics (423 compared to 230). The disparities in the home backgrounds in South Africa are reflected in the data and can be seen when comparing the difference in the international averages. Whilst there is also a difference in the achievement of those who have these resources and those who do not, one does not see such a vast difference in mathematics scores internationally.

Table 7.26
Educational aids in the home

	South African pupils				International pupils			
Educational aids	*% of pupils*	*SE*	*Mean score*	*SE*	*% of pupils*	*SE*	*Mean score*	*SE*
All three aids	8	1.0	415	15.1	41	0.2	516	1.2
Not all aids	92	1.0	265	6.6	59	0.2	471	0.8
Dictionary	75	1.1			90	0.1		
Study desk	56	1.1			86	0.1		
Computer	11	1.1			45	0.2		

Source: Mullis et al, 2000.

South Africa was the only country where these differences equalled or exceeded 150 points between the two groups. Less than 10% of pupils in countries like Indonesia, (6%), Iran (5%), Moldova (5%), Morocco (6%), Thailand (8%) and Turkey (8%) had all three aids as well, but the difference in achievement scores between the "haves" and the "have nots" did not exceed an 80-point difference.

Social Economic Status

A list of items (see Table 7.27) was included in the pupils' questionnaire that was a measure of socio-economic status. Countries had the option to include a number of items that would specifically measure SES in their own contexts. In South Africa, items such as electricity, running water, television, video player, CD player, radio, own bedroom, water flushed toilets, motor car and bicycle were included. As many as 28% of the pupils lived in homes without electricity and 39% where there was no running water. However the majority of pupils had access to the media with 82% having televisions and 93% had radios. The contrast between the language groups of the test is great. Of the Afrikaans group, 94% had electricity and 89% running water compared to the English group where only 67% had electricity and 54% had running water. These figures indicate the well-known low socio-economic levels within which many African people live in South Africa.

Table 7.27

Percentage of pupils with possessions in the home -Social Economic Status (SES)

% of pupils writing the test in	calculator	computer	study desk	dictionary	electricity	running tap water	television	video player	cd player	radio	own bedroom	water flushed toilets	motor car	own bicycle
Afrikaans	91	28	70	88	94	89	94	61	44	97	64	86	60	56
English	85	9	52	73	67	54	80	40	32	92	52	48	42	36
% of SA pupils*	86	12	55	76	72	61	82	44	48	93	54	55	45	39

Note: * % of pupils with possessions in their homes.

Source: South African National dataset.

7.3.3 Pupils' aspirations and attitudes

Pupils' aspirations for the future

Pupils were asked about their expectations regarding their education (see Table 7.28). In South Africa, 53% of pupils reported that they expected to finish university, which was about the same as the pupils internationally (52%). Ten percent of the pupils expected to finish secondary school (less than the international average of 15%) whilst 9% felt that they would only complete some secondary school only compared a low 3% internationally. Both internationally, and in South Africa, it can be seen that the higher the aspirations of the pupils, the higher their achievement scores. For instance, South Africa pupils intending to complete university, achieved on average 292 points compared to those only expecting to finish some secondary school (236). Internationally, there was a larger difference of 127 points between these two groups of pupils. Looking more in-depth at the national picture, the aspirations for education were mostly consistent across groups. However, a higher percentage of pupils in the English group only expected to finish some secondary school.

Table 7.28
Pupils' aspirations of finishing level of education

% of pupils writing the test in	N	Some secondary school	Finish secondary school	Some vocational education	Some university	Finish university	Don't know
Afrikaans	1 309	6	16	9	7	54	9
English	6 230	11	9	12	7	53	7
% of South African pupils	7 598	10	10	12	7	53	8
% of pupils internationally	–	3	15	12	6	52	14

Source: South African National dataset.

Self-concept in mathematics and science

The issue of self-concept in mathematics may be seen as an important outcome of education. An index was developed by the Max Planck Institute based on pupils' responses to four statements about their mathematics and science abilities:

1. I would like mathematics much more if it were not so difficult;
2. Although I do my best mathematics is more difficult for me than for my classmates;
3. Nobody can be good in every subject, and I am just not talented in mathematics/science;
4. Mathematics is not one of my strengths.

A high level indicates that pupils disagree or strongly disagrees with all four statements. A low level shows that pupils agree or strongly agree with all four statements. Therefore a medium category includes all other possibilities.

Table 7.29
Pupils self concept index in mathematics

	High				**Medium**				**Low**			
Country	*% of pupils*	*SE*	*score*	*SE*	*% of pupils*	*SE*	*score*	*SE*	*% of pupils*	*SE*	*score*	*SE*
SA Maths	7	0.7	392	12.7	67	0.9	279	7.2	26	0.9	239	5.5
Int. ave. Maths	18	0.2	547	1.1	67	0.2	486	0.7	15	0.1	436	0.9

Source: Mullis et al, 2000.

Only 7% of South African pupils' fall into the high category regarding mathematics self-concept and these pupils scored 392 points on average (see Table 7.29). Twenty-six percent of South African pupils were found to have a low self-concept and achieved a low 239 points which is significantly below those in the high and medium (279) category. These results are substantially different to the international average where 18% were found in the high category scoring 547 points and only 15% were found in the low category scoring 436 points although the trend was similar. This would indicate that SA pupils have on average an extremely poor self-concept regarding mathematics and this is at the beginning of their secondary schooling. However, on the positive side, no significant gender difference in the self-concept was found amongst South Africa pupils with regard to mathematics.

Generally, those pupils with high self-concept were correspondingly the higher achievers than those with low self-concept. It seems logical that pupils who were confident and liked the subject performed well as opposed to those who lacked confidence and therefore did not like the subject and did not perform well. This is also a self-perpetuating cycle.

Although internationally there appears to be some association between the pupils with higher levels of self-concept and mathematics achievement, it also appears to be strongly influenced by local cultural characteristics. Generally, it would seem that pupils from Westernised countries have far higher levels of self-concept than those from non-Western countries. However, it needs to be noted that the scales used here were designed and developed originally for utilisation in a Western country and perhaps the results may have been different if this had been designed and developed elsewhere.

Positive attitudes towards mathematics

The results presented here are derived from an index that was developed from one question comprising five statements, namely:

1. I like mathematics;
2. I enjoy learning mathematics;
3. mathematics is boring (reversed scale);
4. mathematics is important to everyone's life;
5. I would like a job that involved using mathematics.

An average was computed for the index across the five points based on a 4-point scale (1 being strongly negative and 4 being strongly positive). The four-point scale was then categorised into three groups, high, medium and low. The high group reflects the positive feeling that pupils have towards the subject and the low indicates the negative attitudes. The medium is in between these.

South African pupils were the third highest group of pupils who were rated high, i.e.: positive and 62% of South African pupils reported being positive compared to the low international average of 37%. Only 5% were very low compared to 11% of pupils internationally. South African pupils with very positive attitudes achieved higher scores in mathematics (286 compared to 259 and 264 in the medium and low categories respectively). This same pattern was also found internationally.

The irony is that a very low percentage of pupils from the top performing countries, mostly Asian, were found in the high category, with the exception of Singapore. Most of these countries had two-thirds of their pupils in the medium category with between 10-30% in the low category. In general, countries with low overall scores had the highest percentages of pupils with positive attitudes towards mathematics.

Pupils' perception of the importance of mathematics and language

Pupils were also asked about how important mathematics was and how important English or Afrikaans was (depending on the language of the test they were answering). Apparently, South African pupils are very positive towards mathematics and language and believe that both are important (see Table 7.30). One striking trend is that the pupils' own reported perceptions appear to reflect more positive attitudes towards mathematics than those of their reported perceptions of their mothers and far more so than their reported perceptions of their friends. This was consistent across both mathematics and language. It is possible that pupils wished to put themselves in a good light and so the social desirability factor may have played a role with these results. One might speculate as to whether the pupils' reports about their friends' attitudes towards mathematics and language are a more accurate indicator of the pupils' own attitudes than their own reported attitudes.

Table 7.30

Pupils' and their friends' and mothers' perceptions of the importance of mathematics and the language of the test

Pupils' reports of who considers subjects to be important	Mathematics is important				Language of test is important			
	Strongly agrees	*Agrees*	*Disagrees*	*Strongly disagrees*	*Strongly agrees*	*Agrees*	*Disagrees*	*Strongly disagrees*
Pupil								
% of pupils writing the test in Afrikaans	72.0	24.5	2.9	0.6	73.8	23.8	2.0	0.4
% of pupils writing the test in English	64.3	24.5	6.8	4.4	68.6	21.6	5.6	4.2
Mother								
% of pupils writing the test in Afrikaans	67	25.3	6.1	1.5	69.9	26.5	3.1	0.4
% of pupils writing the test in English	60.1	27.9	7.9	4.1	66.2	23.8	6.1	3.9
Friend								
% of pupils writing the test in Afrikaans	50.9	38.9	8.6	1.6	56.9	34.5	7.5	1.2
% of pupils writing the test in English	56.9	30.1	8.3	4.6	61.9	27.1	6.6	4.4

Source: South African national dataset.

Time spent on Mathematics homework

Pupils were asked to estimate how much time they spent on mathematics homework per week (see Table 7.31). Pupils in the English group reported spending more time on mathematics homework. The same percentage in both groups reported spending no time on homework.

Table 7.31

Time spent on mathematics homework as reported by pupils by language of the test

% of pupils writing the test	N	% of pupils				
		No time on homework	*Less than 1 hour*	*1-2 hours*	*3-5 hours*	*More than 5 hours*
Afrikaans	1 363	9.5	43.5	33	9	5
English	6 230	9.5	35	31.5	14.5	9

Attributes needed to do well in mathematics

Pupils were asked what attributes they felt were needed (ability, luck, hard work or memorising) for them to achieve in mathematics. A four-point scale was used (strongly agree – strongly disagree). Interesting trends may be observed in Table 7.32. Generally the majority of pupils agreed with all four statements. However, more pupils felt that hard work (84%) or memorising (83%) was needed to do well than ability (76%) or luck (74%). The data from the table seem to suggest that generally, the less frequently that pupils felt ability was needed, the higher their scores with the exception of the small percentage that strongly disagreed. The more that pupils disagreed with the notion of good luck, the higher their scores tended to be. This was in contrast to the issue of hard work where the more pupils agreed that this was needed to perform well, the better their scores were likely to be. Likewise, regarding the issue of ability the relationship did not appear to be as linear as with good luck. Pupils that disagreed that it was important to memorise the textbook performed better in mathematics than those that strongly agreed or agreed. However, a small percentage of pupils that strongly disagreed that memorising was important performed on a similar level to those that had agreed. This may be explained by the small percentage of pupils that strongly disagreed that ability was needed or that hard work was needed to do well in mathematics. One suspects that this might be a small percentage of low ability pupils that do not like or do well in mathematics which may explain these results.

Table 7.32

Percentage of pupils that reported on their' perceptions of attributes required, to perform well in mathematics and their mean mathematics scores

		Strongly agree		**Agree**		**Disagree**		**Strongly disagree**	
Attribute	**N**	*% of pupils*	*Mean maths score*	*% of pupils*	*Mean maths score*	*% of pupils*	*Mean maths score*	*% of pupils*	*Mean maths score*
Natural ability	7 738	38	264	38	276	18	303	7	222
Good luck	7 749	44	247	30	265	17.5	330	9	347
Hard work	7 810	56	295	28	259	10	247	5	232
Memorise textbook	7 758	46	267	37	276	13	302	8	270

Source: TIMSS International pupil background almanac.

7.4 PROFILES OF THE TEACHING AND LEARNING ENVIRONMENT FOR MATHEMATICS

In this section, a description of the teaching and learning environment is provided to address the question "who were the mathematics teachers/participants". A description of the teachers is given (7.4.1), followed by the conditions in the mathematics classroom (7.4.2).

7.4.1 A profile of the teachers who participated in TIMSS-R

Age

Thirty-nine percent of the South African pupils in Grade 8, were taught by female mathematics teachers, which is less than the 60% international average. The average age of these teachers was found to be between 28 and 30 years. A minute percentage of teachers over 60 years of age were found in the sample.

The older teachers tended to have classes with higher achievement scores for mathematics. However, in South Africa an exception was found among the teachers who were younger than 25 years whose pupils' achievement was higher than those whose teachers were up to 39 years of age. One explanation to the exception in the trend is that these could be mathematics graduates from university who teach for a year or two and then get absorbed by industry and the private sector and are lost to the education sector. This trend was not observed internationally, with the exception of Singapore. In general, pupils of older and presumably more experienced teachers produced better mathematics results.

In Table 7.33, a summary of the teachers' age and their pupils' mathematics achievement is given.

Table 7.33

Mean age of South African mathematics teachers with South African pupils' mean achievement and the international average

	29 years or younger		**30-39 years**		**40-49 years**		**50-59 years**	
	%	*Pupils' score*	*%*	*Pupils' score*	*%*	*Pupils' score*	*%*	*Pupils' score*
South Africa	29	270	55	264	13	309	3	360
Int. average	16	480	30	489	33	491	21	492

Source: Mullis et al, 2000.

Pupils being taught by the youngest group of teachers achieved the lowest scores on average internationally. It is also interesting that those teachers younger than 40 years of age taught 84% of South Africa's pupils sampled, suggesting that the retention of teachers in this country is very low or alternately that the younger teachers are teaching the younger classes in secondary school. Teachers who were older than 50 years of age taught only 3% of the pupils sampled. It is significant that this group of pupils produced the highest results. It is possible that mature teachers are working in circumstances more conducive to teaching, and it would appear that they view teaching as a vocation and therefore have remained committed to the teaching profession. It is a concern that only 16% of pupils were taught by teachers who may be classed as mature and very experienced, as there appears to be a link between this and pupils' achievement. These figures merely highlight the extent of the instability among the teaching profession.

Teachers' experience

Teachers were asked about their length of experience. Of the 187 teachers that responded, the average length of time was 12.5 years. The longest time in teaching reported by any teacher was 32 years.

Teachers' qualifications

Mathematics teachers reported on their qualifications, both professional teaching qualifications and those in mathematics specifically. These are reported in Table 7.34 in terms of the percentage of pupils whose teachers have these qualifications.

Table 7.34

Mathematics teachers' major area of study in their college diploma, bachelors, masters or teacher training qualification

	% of pupils whose teachers' report having the major area of study*							
	Mathematics		**Mathematics education**		**Education**		**Other**	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	73	3.3	32	3.7	53	4.3	45	4.2
Int. average	71	0.6	31	0.6	32	0.6	32	0.6

Note: * Teachers that responded that they majored in more than one area are reflected in all categories that apply.

Source: Mullis et al, 2000.

On closer inspection of the South African data, three teachers (2%) were found not to have completed secondary school and a further 46 (25%) had completed secondary school only. In total 134 teachers reported having completed a bachelors' or equivalent (meaning their college of education diploma), and two teachers had masters or doctoral degrees. As these groups of teachers are the teachers of a representative sample of pupils, and not a representative sample of all mathematics teachers in the country, one cannot generalise this finding to the whole country, but it certainly gives an indication. It is disturbing to find that a quarter of the teachers are teaching mathematics without qualifications for the subject.

While 89% reported having a training certificate, of those who completed pre-service teacher training 45% reported having started this in their secondary schooling. It would appear that these teachers had completed the old-style education qualification where teacher training started in Standard 8 (Grade 10), trainees studied for two years (equivalent of a matriculation certificate) and obtained their senior teacher's certificate or junior teacher's certificate. As this is regarded below a teacher's diploma from a college of education, it is in no way comparable to university qualifications. Only five teachers had completed this form of training and then gone on to complete a teaching diploma or a university degree.
Perhaps the level of qualifications of the teachers helps to explain their lack of confidence in the preparation to teach mathematics. Only half of the pupils' teachers reported being confident about teaching mathematics. An index was constructed by the study on the basis of 12 questions about how prepared they felt to teach different mathematics topics based on a three point scale (1 = not well prepared, 2 = somewhat prepared, and 3 = very well prepared). A high level indicates the average is greater than or equal to 2.75. A medium level indicates that the average is greater than or equal to 2.25 and less than 2.75. A low level indicates than the average is less than 2.25.

Once again, it is ironic that it is not the teachers of the high achieving nations that appear most confident to teach those topics, but rather teachers from Macedonia, USA, the Slovak Republic, Cyprus and Jordan. In contrast, the Japanese teachers appear the least confident with only 8% being found in the high category (as opposed to 92% of Macedonians and 87% of Americans) compared to 63% of pupils' teachers internationally. South African teachers also did not appear confident as only 54% were found in the high category. However, they did not lack confidence completely as only 14% (comparable to the international average) were found in the low category compared to 21% of pupils' teachers in Korea and 68% in Japan. Given the South African pupils' very poor performance and the Japanese pupils' excellent performance, one might have expected the reverse situation to be true.

Teacher beliefs about mathematics

The TIMSS-teacher background questionnaire has a number of questions about 'mathematics orientations of teachers'. In designing the questionnaire, each question represented an orientation, for example:

- The 'inductive mathematical orientation' was operationalised in 'mathematics is primarily a formal way of representing the real world', and;
- The 'inductive mathematical technological orientation' in 'mathematics is primarily a practical and structural guide for addressing real situations'.

In Table 7.35, each of the six items is given with the South African pupils' and international pupils' responses as well.

In general, relatively few teachers disagreed with the statements. A far higher percentage of South African teachers[4] tended to agree strongly with the statements compared to those internationally. However, a far greater percentage of the pupils' teachers disagreed with the last statement regarding teachers needing only basic computational skills, although lower percentage of South Africans (47% of pupils' teachers) compared to their international counterparts (72%).

In general, pupils of South African teachers who tended to disagree (strongly or otherwise) with the statements achieved higher scores in mathematics. Interestingly, no such trend was discernible amongst the international averages.

[4] A far higher percentage of the pupils' teachers.

Table 7.35
Teachers' pedagogical beliefs about mathematics

Pedagogical Beliefs	N	Strongly Disagree		Disagree		Agree		Strongly Agree	
		% of pupils	*Mean score*	*% of pupils*	*Mean score*	*% of pupils*	*Mean score*	*% of pupils*	*Mean score*
Mathematics is primarily a formal way of representing the real world									
South Africa	183	3	309	11	340	53	281	33	242
International	179	6	484	27	457	54	488	15	486
Mathematics is primarily a practical and structural guide for addressing real situations									
South Africa	183	1	348	9	318	44	289	46	251
International	180	3	480	15	490	61	487	23	488
If pupils are having difficulty, an effective approach is to give them more practice by themselves during class									
South Africa	187	3	297	15	306	36	281	45	261
International	181	6	486	28	488	46	488	22	485
More than one represen-tation (picture, concrete material, symbol set etc.) should be used in teaching a mathematics topic									
South Africa	187	1	238	4	334	46	280	49	268
International	182	3	451	5	491	47	487	49	491
Mathematics should be learned as sets of algorithms or rules that cover all possibilities									
South Africa	182	7	282	30	311	41	262	23	256
International	178	7	479	38	491	44	485	11	489
Basic computational skills on the part of the teacher are sufficient for teaching secondary school mathematics									
South Africa	186	18	340	29	288	31	248	23	250
International	181	30	493	42	488	19	482	11	474

Source: TIMSS Mathematics Teacher background Almanac, pp.46-52.

7.4.2 Conditions within the mathematics classroom

Instructional time

On average, teachers reported that there were 136 hours a year instructional time for Grade 8 pupils in mathematics. This compares to 129 hours on average internationally. Unfortunately, less than 70% of both the principals and teachers in South Africa provided information on time on task, and therefore a percentage of total instructional time could not be calculated. However, internationally on average pupils spent 13% of their instructional time on mathematics.

An inspection of Table 7.36 does not reveal any difference in achievement between groups of pupils who spent less than 2 hours per week of instructional time on mathematics compared to those spending five hours or more.

Table 7.36
Number of hours that mathematics is taught weekly in South African schools and pupils' mean mathematics score

	5 hours or more				**3.5 hours to ,5**				**2 hours to ,3.5**				**Less than 2 hours**			
	% pupils	*SE*	*Maths Score*	*SE*	*% pupils*	*SE*	*Maths Score*	*SE*	*% pupils*	*SE*	*Maths Score*	*SE*	*% pupils*	*SE*	*Maths Score*	*SE*
South Africa average	9	2.6	275	24.4	58	4.2	277	8.8	23	3.5	269	13.3	10	2.4	273	17.2
Int. average	9	0.3	481	3.5	34	0.5	492	2.3	53	0.5	490	1.9	4	0.3	485	4.7

Source: Mullis et al, 2000.

By far the majority of schools in South Africa (91%) (and internationally) spend less than five hours per week on mathematics. However, whereas 67% of South African schools spend more than 3.5 hours per week, only 43% on average do so internationally. Internationally only 4% of schools on average spend less than two hours per week compared to 10% of South African schools. As can be seen from Table 7.36, there appears to be little difference in the achievement levels on average between the groups and the amount of time on task. However, the large standard errors in the exhibit signify that both high and low achieving schools fall within each time category and therefore the relationship between time and achievement needs further investigation.

Class size

South Africa and the Philippines had the largest class size on average for mathematics internationally. On average these countries had 50 pupils per class in contrast to the international average of 30 pupils. South Africa had a large standard error (1.4), signifying the diversity within the system and illustrating that there are quite a number of smaller classes in the sample. Only 2% of South African pupils attended classes where there were less than 20 pupils.

However, while 85% of South African pupils are in classes of 36 or more pupils, a higher percentage of pupils from Chinese Taipei (86%), Indonesia (89%), Korea (88%) and the Philippines (95%) were found in classes of this size. As these countries included some of the highest achievers in the study, cross-nationally the association between class size and achievement does not appear to be significant on its own.

Classroom practice

Teachers were asked to indicate the average time spent on various activities in the mathematics class on average in a typical month. South African teachers spent far more class time on administrative tasks (13%) than any other country (5% on average). They also reported spending a significant percentage of their time on reviewing homework (26% compared to 12% on average internationally). (See Table 7.37.)

Table 7.37

Time spent on various activities in class according to teachers

	Average percentage of class time spent in a typical month of lessons															
	Administrative tasks		**Homework review**		**Lecture-style presentation by teacher**		**Teacher guided pupil practice**		**Re-teaching and clarification of content/ procedures**		**Pupil independent practice**		**Tests and quizzes**		**other**	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	13	1.4	26	1.6	23	1.8	26	1.7	21	1.6	21	1.8	22	1.3	7	1.1
Int. ave.	5	0.1	12	0.1	23	0.2	22	0.2	13	0.1	15	0.2	11	0.1	4	0.1

Source: Mullis et al, 2000.

Significantly, more time was spent in South African classrooms (21%) on re-teaching and clarification of content or procedures than in other countries on average (13%). This suggests that only limited time is being spent on the teaching of mathematics, resulting in many pupils arriving in Grade 8 mathematics classes with less than adequate preparation for that grade. The fact that the largest standard error was also recorded for South Africa on this item indicates that there are several classes where this is not an issue, again signifying the diversity between the classes. Substantially more time was spent on pupil independent practice (21%) in South African classes than on average internationally (15%). However, in countries like Australia, England, Finland, and the Netherlands (the most of all countries at 32%) more time was spent on pupil independent practice. A relatively high percentage of time was spent in South Africa classrooms on tests and quizzes (22%) compared to 11% internationally. Interestingly, the only other country spending as much time on this item was Iran.

Pupils were also asked about the various activities that they do in their mathematics class. (See Table 7.38) These reports seem to concur with teachers' reports about pupils' independent working (working on worksheets and projects) generally. A relatively high percentage of South African pupils discuss their homework in class (72%). In countries such as Japan and Korea, very few pupils reported this (19% and 10% respectively), whereas in the USA, 79% of pupils reported this. Likewise, there were substantial differences regarding beginning homework in class. A higher percentage of South African pupils (69%) reported doing this compared to the international average of 42%. The highest percentages of pupils who reported doing this were found in the Netherlands and Canada (89% and 82% respectively), whereas only 17% of Korean, 16% of Czech, 13% of Indonesian and 10% of Russian pupils start their homework in class.

Table 7.38
Pupils reporting doing various activities in mathematics class

	Percentage of pupils reporting almost always or pretty often									
	We discuss our homework in class		**Teacher show us how to do mathematics problems**		**We work on worksheets or textbooks on our own**		**We work on mathematics projects**		**We begin our homework in class**	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	72	0.8	83	0.7	67	1.2	59	1.4	69	1.1
Int. average	55	0.2	86	0.2	59	0.2	36	0.2	42	0.2

Source: Mullis et al, 2000.

Teachers' emphasis on mathematics reasoning and problem solving in class

An index for mathematics reasoning and problem solving was constructed by the study based on teachers' responses to four questions about how often they asked the pupils to:

- explain the reasoning behind an idea;
- represent and analyse relationships using tables, charts and graphs;
- work on problems for which there is no immediately obvious method of solution;
- write equations to represent relationships.

The average was computed across the four items based on a 4-point scale: 1 = never or almost never; 2 = some lessons; 3 = most lessons; 4 = every lesson. A high level indicates that the average is equal to or greater than 3. A medium level indicates that the average is greater to or equal to 2.25 and less than 3. A low level indicates the average is less than 2.25. (See Table 7.39.)

Table 7.39

Teachers' reports on their emphasis on mathematics reasoning and problem-solving in class

	High				**Medium**				**Low**			
	% of pupils		**Average score**		**% of pupils**		**Average score**		**% of pupils**		**Average score**	
	%	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*
South Africa	16	3.1	260	12.8	58	3.8	269	7.6	26	2.9	303	15.6
Int. average	15	0.5	493	3.5	61	0.7	490	1.0	24	0.6	479	1.5

Source: Mullis et al, 2000.

Teachers of 16% of South African pupils placed a high emphasis on mathematics reasoning and problem solving, which is comparable to the international average. The country with the highest percentage of pupils' teachers emphasising this approach was Japan (49%). A low percentage of pupils' teachers in Morocco (7%) and Tunisia (8%) reported this emphasis. While the trend internationally appeared to be that pupils of teachers following this approach would achieve a corresponding higher achievement, this was not the case with South African mathematics where the trend was in the opposite direction. Pupils whose teachers reported placing a high emphasis on this aspect achieved lower results (260 points) compared to pupils whose teachers placed a lower emphasis on this (303 points).

Calculator use in classrooms

Of South African pupils, 89% have access to calculators in class, which is comparable to the international average of 88%. Countries like Chinese Taipei (51%), Japan (34%), Malaysia (34%) and Korea (28%) have much lower percentages of pupils having access to the calculators. In contrast, England, the Netherlands and Singapore reported 100% of their pupils having access to calculators in class.

Table 7.40

Teachers' reports on the use of calculators in mathematics classes in South Africa

	Unrestricted use				**Restricted use**				**Calculators not permitted**			
	% of pupils		**Average score**		**% of pupils**		**Average score**		**% of pupils**		**Average score**	
	%	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*
South Africa	28	4.3	280	12.8	61	4.7	274	9.0	11	3.2	299	27.7
Int. average	21	0.5	490	2.2	67	0.7	488	1.2	12	0.6	464	3.5

Source: Mullis et al, 2000.

On average, a higher percentage of South African pupils (28%) were permitted unrestricted use of calculators in class than the international average of 21% (See Table 7.40). Only 11% of pupils in South Africa are in classes where calculators are not permitted, compared to 55% of Malaysian pupils and 42% of Iranian pupils. The majority of high achieving countries' pupils (Chinese Taipei, 85%; Japan, 85%; Singapore, 69%; Korea, 77%), with the exception of Hong Kong (32%), have restricted use of calculators in class. Internationally, there seems to be little difference in achievement between unrestricted and restricted calculator usage and achievement, but there does seem to be a substantial difference between using calculators and not using calculators and achievement. Here again, the South African situation is different, as there does not seem to be this trend.

Emphasis on calculator use in classrooms

An index was constructed to ascertain the extent of the emphasis put on calculator use in the classroom. This was based on the pupils' reports of the frequency of using calculators in mathematics lessons and teachers' reports of pupils' use of calculators in mathematics class for five activities: checking answers; tests and exams; routine computation; solving complex problems; and exploring number concepts. A high level indicates that the pupils reported using calculators in mathematics always or often and that the teacher reported that pupils use calculators at least once or twice a week for any of the tasks. A low level indicates that the pupils reported using the calculators once in a while or never and that the teacher reported pupils use calculators never or hardly even for all of the tasks. A medium level includes all other possible combinations of responses.

A higher percentage of South African pupils were recorded in the high category compared to the international average (See Table 7.41). Therefore, according to both the teachers and the pupils, pupils are using calculators frequently in class. Out of 38 countries, South Africa had the 11th highest percentage of pupils using calculators. The highest percentage of pupils in the high category was found in the Netherlands (95%), followed by Singapore (85%), compared to 0% of Korean and Japanese pupils. Only 2% of Chinese Taipei and 1% of Malaysian pupils were found in the high category. Internationally there was no pattern regarding achievement and the emphasis on calculators and countries varied tremendously on this variable. However, in South Africa pupils in the low category tended to achieve higher scores in mathematics.

Table 7.41
Emphasis on calculator use in mathematics classes in South Africa

	High				Medium				Low			
	% of pupils		Average score		% of pupils		Average score		% of pupils		Average score	
	%	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*
South Africa	51	2.8	280	9.9	40	1.9	266	7.3	10	2.0	314	24.3
Int. average	32	0.3	481	1.8	42	0.5	484	1.2	26	0.5	481	3.3

Source: Mullis et al, 2000.

Teachers' emphasis on homework

An index was constructed on the basis of teachers' answers to two questions about how often they usually assigned homework and how many minutes of mathematics homework they usually assigned. A high level indicates the assignment of more than 30 minutes of homework at least once or twice a week. A low level indicates the assignment of less than once a week or never assigning homework. A medium level includes all other possibilities.

Table 7.42
Index of teachers' emphasis on mathematics homework

	High				Medium				Low			
	% of pupils		Average score		% of pupils		Average score		% of pupils		Average score	
	%	*SE*	*Score*	*SE*	*%*	*SE*	*score*	*SE*	*%*	*SE*	*score*	*SE*
South Africa	25	3.1	261	9.9	75	3.1	281	7.8	0	0.0	--	--
Int. ave.	35	0.6	491	1.8	62	0.6	485	1.0	4	0.2	484	4.0

Source: Mullis et al, 2000.

Of South African pupils, 25% were given more than 30 minutes of homework at least once or twice a week, which is less than the international average of 35% (See Table 7.42). This was lower than Malaysia (72%), Singapore (66%), Chinese Taipei (48%) and Hong Kong (41%) among others, although higher than Japan (11%). Internationally, there seems to be a relatively high emphasis on mathematics homework. Only 4% of pupils internationally get less than 30 minutes of homework less than once a week, and this does not appear to happen in South African schools and in 12 other countries. Thirty-four percent of Japanese pupils are given less than 30 minutes of homework less than once a week. This relatively high figure is probably explained due to the large percentage of pupils who attend extramural academic activities, especially in mathematics. Although there appears to be a trend internationally towards more homework being linked to higher achievement, this is clearly not the case in South Africa.

Pupils' perceptions of classroom environment

Pupils were also asked questions about the behaviour of their peers in class to provide a measure for the classroom environment (see Table 7.43). More than one-third strongly agreed that their peers neglected their work in class and only 25% reported that pupils did not neglect their work. Almost one-third reported that pupils were not quiet and orderly in class, although 70% of the pupils reported that they were quiet and orderly. In contrast to the international figures (66%), 77% of pupils reported that pupils obeyed the teacher. Whilst 46% of South African pupils reported that they strongly agreed that pupils obeyed their teachers only 22% of pupils internationally reported that this was the case.

Table 7.43
Pupils' reports about their learning environment

	% of pupils reporting											
	Students neglect their work in class				Students are quiet and orderly in class				Students do what the teacher asks			
	Strongly agrees	*Agrees*	*Disagrees*	*Strongly disagrees*	*Strongly agrees*	*Agrees*	*Disagrees*	*Strongly disagrees*	*Strongly agrees*	*Agrees*	*Disagrees*	*Strongly disagrees*
South Africa	38	37	16	9	35	35	20	10	46	31	15	8
Int. ave.	16	38	36	11	19	39	33	9	22	44	28	7

Source: Mullis et al, 2000.

7.5 SCHOOL BACKGROUND CHARACTERISTICS

The focus of this section is the environment in which schooling in South Africa takes place and addresses the question of "*who were the participants*?" in terms of the schools participating. The location, leadership matters, issues pertaining to the curriculum, resources and the problems in the schools are discussed here.

7.5.1 A profile of South African schools participating in TIMSS

Geographic location of schools

Of key importance is the geographic location of South African schools and its possible influence on the achievement of the pupils. As can be seen in Table 7.44, the majority of the schools sampled (40 %) are located in villages or rural areas while 3% are located in geographically isolated areas.

Of the schools in the sample, 32% are close to the centre of a town or city and 25% percent of the schools are on the outskirts of a town or a city. The split of the schools in the sample reflects the broader population of the country, as approximately half of the country's people live in the rural areas.

Table 7.44
The geographic location of South African TIMSS-R schools

Location	% of Schools
Schools in geographically isolated areas	3
Schools in village or rural areas	40
Schools located on the outskirts of a town or city	25
Schools located close to the centre of a town or city	32

Number of teaching staff

The numbers of teachers vary across the schools in the sample. The average number of full-time teachers was found to be 21, with the range varying from 1 to 100. Very few schools reported that they had part-time teachers in their employ. Principals reported that on average 68% of their teachers had been in their employ for five years or longer.

Teacher:pupil ratio

According to the White Paper on Education (DoE, 1995: 19) the teacher-pupil ratio for any given class in secondary schools should be 35:1. However, amongst the schools participating in TIMSS-R, the average Grade 8 class had 46 pupils, although the largest class had 95 pupils.

Number of pupils enrolled in the schools

The enrolment of pupils per school varied across the schools and there were 854 pupils on average enrolled in the schools. The smallest enrolment was found to be 66, in a rural area, while the largest enrolment was found to be 1957, an urban school. In general on average more pupils are enrolled annually in urban schools (1 028) than in rural schools (622).

Admission Criteria to schools

Access to schooling is determined by various criteria. The importance of admissions criteria varied between the schools, as seen in Table 7.45. Most of the schools appear to be accessible to all pupils. The most commonly found criterion for access to schools was that the pupils should live in the local area of the school. The closing date of application seems enforced in at least 49% of the schools. According to the South African Schools Act of 1996, a government school must admit pupils and serve their educational requirements without unfairly discriminating in any way. Being a local resident appears to be an important criterion in more than half (53%) of the schools. Of the schools in the sample, 34% (of the pupils' principals) indicated that pupils were allowed into the schools on the basis of their academic performance, while 16% indicated that preference was given to pupils from a particular school. The governing body of the school may not administer any test, which relates to the admission of the pupil or authorise that the principal of the school or any other person administer a test in this regard. Among the TIMSS-R sample, it was found that 13% of the schools made use of standardised testing when considering applicants, 13% made use of entrance examinations, and 9% made use of oral examinations.

Table 7.45

Criteria for admission to South African schools as reported by principals

Criteria	**Percentage of pupils**	**SE**
Living in the area	53	5.3
Date of application	49	5.2
Academic performance	34	5.2
Brothers or sisters who are already in the school	13	3.9
Recommendations from previous teachers	22	4.4
Interviews with the pupils	20	4.4
Interviews with the parents	25	4.5
Preference given to pupils from a particular school	16	2.8
Standardised testing	13	4.0
Entrance examinations	13	4.1
Oral examinations	9	3.6

Note: More than one criterion may apply per school.

Source: Howie, 2001.

Schools expectations of parental role

The school has certain expectations of the parents of the pupils who attend. In South Africa the schools expect the parents to ensure that their children complete their homework, to volunteer for school projects, programmes or fieldtrips, to raise funds for the school, and to serve on committees. (See Table 7.46.)

Table 7.46

Principals' reports about the schools' expectations for parental involvement in their child's education

	% of pupils									
	Be sure child completes homework		Serve as a teacher aid in classrooms		Volunteer for school projects, programmes or field trips		Raise funds for the school		Serve on committees	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	93	1.8	39	4.4	97	1.2	87	2.4	99	0.8
Int. average	85	0.5	28	0.6	79	0.5	51	0.6	47	0.6

Source: Mullis et al, 2001.

7.5.2 Leadership of South African schools

In order for schools to function well it is important that the leadership of the school is effective in managing the school. In this section, the role played by school governing bodies, principals, head of departments, teachers and parents is discussed.

Responsibilities of school governing bodies

According to the South African Schools Act (RSA, 1996), the governance of every government school is vested in its governing body and the governing body stands in a position of trust towards the school. The school governing body (SGB) comprises the principal of the school and representatives of parents, teachers, non-educator members of staff, and pupils (in secondary schools). Table 7.47 outlines the responsibilities of governing bodies according to principals.

It would seem that most school governing bodies were responsible for the formulation of the disciplinary policy, for the budget and for hiring teachers. However, they appeared to have little influence in the majority of schools in determining the course content and communicating with pupils' families.

Table 7.47

Percentage of pupils' whose principals report on the responsibilities of the governing body

Task	% of pupils
Hiring of teachers	67%
Formulation of disciplinary policy	70%
Establishing of the grading policy	10%
Formulation of the budget	71%
Purchasing of supplies	35%
Establishment of community relationships	43%
Communication with pupils' families	15%
Deciding on the courses offered	29%
Influencing the curriculum taught	23%
Determination of course content	6%

Source: Howie, 2001.

Responsibilities of the principals

Principals were asked how they divide their time on a monthly basis between the various activities in which they take part (see Table 7.48). The amount of hours spent by pupils' principals appears to be lacking in the areas of instructional leadership activities and administrative duties when compared to the international average. The amount of teaching, which includes preparation, is above the international average.

Table 7.48

Average total hours per month South African principals report spending on activities

	Instructional leadership activities		Communicating with pupils' parents and educational officials		Administrative duties		Teaching including preparation	
	Hours	*SE*	*Hours*	*SE*	*Hours*	*SE*	*Hours*	*SE*
South Africa	19	1.2	34	2.3	43	3.4	22	2.6
Int. average	33	0.3	35	0.3	51	0.5	16	0.2

Note: The cumulative percentage may be more than 100% due to rounding off of decimals.
Source: Mullis et al, 2000.

Responsibilities of heads of departments and teachers

The principals of less than half (41%) of pupils reported that the responsibility for selecting the textbooks was equally that of the heads of department and the teachers. Responsibility for establishing homework policies were delegated to the department heads by 45% of schools. Placement of pupils in classes was the responsibility of the teachers according to 42% of the principals. The head of department does influence the curriculum taught according to 51% of the principals, but the principals of only 27% of the pupils indicated that determining course content was a responsibility of the head of department while 11% reported that the responsibility of selecting the courses offered was the responsibility of the heads of department.

Very little responsibility regarding disciplinary policies and formulation of the budget is given to teachers and heads of department (see Table 7.49).

Table 7.49
Responsibilities of heads of departments and teachers as reported by South African school principals

	% of pupils	
Activity	*Head of Department*	*Teachers*
Disciplinary policy	1	6
Grading policies	24	16
Purchasing of supplies	14	6
Placement of pupils in classes	38	42
Assigning teachers to classes	31	2
Formulation of the budget	1	4
Selection of textbooks	41	41
Homework policies	45	33
Course content	27	11
Courses offered	11	14
Influence on the curriculum taught	51	42
Communicating with families	3	24

Source: Howie, 2001.

Instructional time available for Grade 8 pupils in South African schools

The number of instructional days reported by principals for Grade 8 pupils for the school year range from 120 to 280 with the average being 195 days. The number of full instructional days (meaning a day with over four hours) for a typical calendar week (Monday through Sunday) varied. The majority (91%) indicated that there were five full instructional days in their calendar week (four hours or longer each day). Of the rest, 7% indicated that they had only three or four full instructional days.

Although in the majority of the cases full-day instructional time is made available, it is worrying that there are cases in which this is not happening. A total of 15% of the pupils' principals indicated that there were one or more half days. One has to ask whether this provides pupils with enough opportunity to learn and to equip them with the skills that they need.

The amount of instructional periods per week varied in these schools from 10 to 96, with the average being 43 periods per week. The duration of these periods also varied from 15 minutes to 120 minutes; the average time per period was 38 minutes.

Resources available in South African schools

Adequate resources are believed to be essential for quality teaching and learning to take place in a school. Principals were asked whether the school's capacity to provide instruction was affected by a shortage or inadequacy of a number of things. Their responses are summarised in Table 7.50.

Table 7.50

Shortage or inadequacies in general facilities and materials that affect schools' capacity to provide mathematics instruction some or a lot

	% of pupils									
	Instructional materials		**Budget for supplies**		**School buildings & grounds**		**Heating/ cooling & lighting**		**Instructional space**	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	67	4.1	66	4.1	61	4.3	59	4.1	57	3.7
Int. average	45	0.6	47	0.6	50	0.7	36	0.6	47	0.6

Source: Howie, 2001.

South African principals of 67% of the pupils indicated that their capacity for effective schooling was affected "a lot" by the lack of or inadequacy of instructional materials such as textbooks. Materials such as textbooks are essential learning aids, particularly for pupils from deprived home backgrounds. The budgeting of supplies was a hurdle for the pupils' principals in 66% of the schools sampled, while 61% of the pupils' principals indicated that the shortage of school buildings and grounds affected them negatively. A shortage of lighting and heating was considered to be a problem by 59% of the principals. Pupils need space in order to be able to work effectively and 57% of the pupils' principals indicated that the space available was inadequate and that the school's capacity was affected.

More South African principals (and more pupils were affected by) a greater shortage or inadequacy regarding school facilities than those internationally reported. In particular, more South African principals reported a greater shortage of instructional materials and heating, cooling and lighting facilities than their international counterparts.

With regard to the resources, equipment and materials for mathematics specifically (see Table 7.51), principals of more than 70% of the South African pupils indicated that there was a lack of computers and computer software for both mathematics. This is not surprising because only approximately 10% of South African schools have computers.

Principals of 67% of the pupils indicated that a lack of calculators was a problem. However, according to the Grade 8 pupils specifically (of which 86% have calculators), this is not a serious problem. Principals of more than 70% of the pupils indicated that the shortage or inadequacy of library materials and audio-visual resources affected their school's capacity for learning.

Comparatively, South African principals reported that their capacity was affected more than the international average. However, higher percentages of pupils' principals from countries such as Moldova, Macedonia (in all five categories), especially, but also from Romania, Russia and the Slovak republic (in three out of the five categories) reported that their work was hampered by shortages and inadequacies overall than South Africa. Nonetheless, their pupils attained higher scores.

Table 7.51
Shortages or inadequacies of equipment or materials for mathematics instruction that affect the schools' capacity to provide instruction in mathematics some or a lot

	% of pupils									
	Computers for mathematics instruction		**Computer software for mathematics instruction**		**Calculators for mathematics instruction**		**Library materials relevant to mathematics instruction**		**Audiovisual resources available for mathematics instruction**	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	76	3.2	74	3.6	67	4.1	74	3.5	75	3.9
Int. average	57	0.7	59	0.7	35	0.6	46	0.6	50	0.6

Source: Mullis et al, 2000.

The environment in South African schools

The atmosphere within a school is important in terms of whether or not it is conducive to learning. The principals were asked whether or not there was an official policy regarding promoting co-operation and collaboration among teachers. In 83% of the cases it was found that such a policy did exist. According to principals of 97% of the pupils teachers are encouraged to share their instructional ideas and materials with each other within their schools, and 83% of the principals indicated that teachers do meet regularly to discuss instructional goals and issues. However, it was also observed that the principals themselves do not spend much time on this type of activity with their teachers. A close examination of the mathematics teacher data revealed that 53% of the teachers reported meeting once a month or more regularly, with 6% meeting twice or three times a week.

Internationally, there is an intense debate about the decentralisation of authority and the need for or benefit of autonomy for the schools. The principals were asked whether or not they have their own written statement of the curriculum content to be taught. In South Africa, principals of 77% of the pupils indicated that they did not have such a written statement for mathematics. The average internationally for not having a written statement for mathematics was also high, viz. 65%. In South Africa, principals of 48% of the pupils indicated that they had developed instructional activities or learning materials for mathematics.

Behavioural problems in South African schools

The following tables compare the four most frequent and most serious problems as reported by the school principals to the relevant international average.

More than 40% of the principals indicated that arriving late at school and absenteeism are serious problems (see Table 7.52), and more than 65% of the pupils' principals indicated that these behavioural problems occur at least weekly. Principals of 36% of the pupils felt that skipping of classes is a serious problem and 57% indicated that this occurs weekly.

Table 7.52

Frequency and seriousness of pupil attendance problems (percentage of pupils)

	% of pupils											
	Arriving Late				**Absenteeism**				**Skipping Class**			
	Occurs at least weekly		*Is a serious problem*		*Occurs at least weekly*		*Is a serious problem*		*Occurs at least weekly*		*Is a serious problem*	
	%	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*%*	*SE*
South Africa	75	3.6	48	4.5	69	3.6	46	3.9	57	4.4	36	3.5
Int. average	49	0.6	11	0.4	38	0.6	17	0.5	27	0.6	13	0.5

Source: Mullis et al, 2000.

According to Martin, Mullis & Gregory, *et al.* (2000a), the violation of the dress code is likely to reflect whether there is a uniform requirement in general. In the majority of South African schools the pupils are required to wear uniforms. Principals of 33% of the pupils (see Table 7.53) indicated that this was a serious problem and 60% indicated that violation of the dress code occurs at least on a weekly basis.

Table 7.53
Frequency and seriousness of pupil's violating dress code

	Violating the dress code			
	Occurs at least weekly		**Is a serious problem**	
	% of pupils	*SE*	*% of pupils*	*SE*
South Africa	60	4.2	33	3.3
Int. average	24	0.6	6	0.3

Source: Mullis et al, 2001.

Principals of 29% of the pupils indicated that theft was a serious problem in schools (see Table 7.54) and 16% indicated that theft occurred at least on a weekly basis, which is considerably higher than the international average.

Table 7.54
Frequency and seriousness of pupils committing theft at school

	Theft			
	Occurs at least weekly		**Is a serious problem**	
	% of pupils	*SE*	*% of pupils*	*SE*
South Africa	16	2.7	29	4.2
Int. average	6	0.3	12	0.5

Source: Mullis et al, 2000.

The index of good school and class attendance is based on the school's responses to three questions related to the seriousness of attendance problems in the school, arriving late at school, absenteeism and skipping of classes. A high level indicates that all three of the behaviours mentioned are not a problem in the school. A low level indicates that either two or three of the behaviours are a serious problem or that two of the behaviours are minor problems while the third behaviour is a serious problem. A medium level indicates all other possible combinations of responses.

As can be seen from Table 7.55, a large percentage (53%) of the pupils fall within the low level, which indicates that problems are being experienced. It is therefore not surprising that the average achievement in this category was found to be 212 points (out of 800). Even on a medium level (which has a large percentage of 44) problems are experienced and the achievement average (270), although better than on a low level, is still well below the international average of 487. However, pupils within the High category appear to benefit from good attendance at school (386 points) and achieve more than 110 points more than those in schools reporting attendance problems.

Table 7.55
Index of good school and class attendance and performance in mathematics

	High				Medium				Low			
	Percent of pupils		**Average Achievement**		**Percent of pupils**		**Average Achievement**		**Percent of pupils**		**Average Achievement**	
	%	*SE*	*Mean score*	*SE*	*%*	*SE*	*Mean score*	*SE*	*%*	*SE*	*Mean score*	*SE*
South Africa	3	1.2	386	44.1	44	3.9	270	15.4	53	4.0	212	9.7
Int. average	20	0.6	498	2.5	60	0.7	487	1.0	19	0.5	474	2.0

Source: Mullis et al, 2000.

7.6 CONCLUSION

The South African mean score of 275 scale points was well below the international mean of 487 points and significantly below the mean scores of all other participating countries, including the two other African countries of Morocco and Tunisia as well as that of Malaysia, the Philippines, Indonesia and Chile. Pupils in the Western Cape achieved the highest score with 381 points, but this was still significantly below the international mean score of 487. The gender difference in the South African results was not statistically significant. The scores appear to reveal a trend that pupils that speak the language of the test more frequently also attain higher scores on the mathematics test. When comparing those pupils that almost always or always speak the language of the test to those that never speak the language of the test, the former achieve scores that are more than 140 points higher than the latter. White pupils' scores are substantially higher than those of other groups and that of the groups the most disadvantaged group previously (African) would attain the lowest scores. However, what is worth noting is that despite being considered the most advantaged group (and about 100 points above the national mean score), the white pupils' mean score was nonetheless more than 100 points below the international mean score.

South African pupils' performance was relatively low in every mathematics content area. For South Africa, the average score for data representation, analysis and probability is the highest score of 356 points relative to the international average. Ironically, this is also the area not included in the intended curriculum at Grade 8 level.

The average language test score was very poor (16 out of 40). The minimum score attained was 0 and the maximum score 40. In general, the scores for boys and girls were comparable. Pupils in the wealthiest and most urbanised provinces (Gauteng and Western Cape attained the highest overall scores on the language test.

Pupils' background

An analysis of the background variables revealed a number of differences between South African pupils and their peers in other countries. South African pupils were on average older than their counterparts and most of them attended schools where the medium of instruction (and hence of the tests) was different to the language spoken at home. A large percentage of South African parents had only finished primary school, and in more than two-thirds of the homes there were very few books. South African pupils reported spending more time on homework in mathematics and science than those internationally. Very few of them had a high self-concept with regard to mathematics although they were on the whole very positive about the subject. Their aspirations were also higher than children internationally, as more than half wanted to study at university after school.

Mathematics teachers

On the whole South African Grade 8 mathematics teachers were young and mostly male. However, the data suggest that the pupils of the more mature teachers produced higher scores in mathematics. A quarter of the mathematics teachers were not qualified to teach and had not completed education beyond secondary school. Therefore, it is not surprising that a high percentage of teachers reported lacking confidence to teach mathematics. Most teachers had to teach large classes in Grade 8, with the average size being about 50 for mathematics. South African Grade 8 mathematics teachers spent more time on administration than their counterparts in other countries. They also spent substantially more time re-teaching topics that should have been covered in the lower grades, but where the pupils' knowledge and skills were obviously insufficient. Teachers also spent more time discussing pupils' homework in contrast to Asian countries in particular. However, fewer South African pupils (than internationally on average) did less homework for mathematics and did this less frequently (than the international average). The teachers' emphasis on mathematics reasoning and problem solving was comparable to other countries. A higher percentage of South African pupils also had comparatively unrestricted use of calculators more frequently.

South African Schools in TIMSS-R

Approximately half the schools in the study were in rural areas. The admissions requirements differed, with the most common criteria relating to residence, date of application and academic performance. An interesting difference between schools nationally and internationally, which may be largely attributed to the introduction of school governing bodies, was that almost all (99%) South African schools expected the parents to serve on committees whereas less than half of schools internationally had such an expectation. While the role of the governing bodies was clear according to the principals, namely the formulation of disciplinary policy, budget and hiring teachers, the role of the teacher in many schools was quite constrained; responsibilities were limited on the whole to the placement of pupils in classes, textbook selection and influencing the curriculum they deliver.

Several aspects affected the capacity of more than half of the schools. Of these, resources were most commonly reported and were very limited in many schools especially with regard to the lack of instructional materials. Other problems affecting schooling and learning were high rates of absenteeism and skipping class and even injury to teachers and pupils in a small percentage of schools.

Overall, the data provide a profile of the disparities that exist in the education system, but more overwhelmingly in terms of the social economic realities across society as a whole. Most importantly, they provide one with an insight into the poor performance of South African pupils and suggest that the "system has failed the pupils" not that "the pupils have failed the system". Clearly the data confirms that the problems are not ad hoc, but rather of a systemic nature with strong socio-economic influences.

CHAPTER 8
Results of the partial least squares analysis

An analysis of the student-, class and school-level models was done using Partial Least Squares (PLS) analysis. The factors to be explored were discussed in Chapter 6 and were based on the literature, on knowledge of the context and finally, were limited to, those found in the TIMSS-R database. First 22 factors were explored in the pupils' data that were believed to influence South African pupils' achievement in mathematics. The classroom-level model investigated 14 factors and a school-level model a further 13 factors. The school and classroom models were finally combined into a final school-level model which revealed that the pupils' achievement was explained by six significant predictors: location of the school, class size, the attitude of the teacher, teachers' beliefs about mathematics, the teachers' workload (including teaching) and their dedication toward lesson preparation. Eight variables explained 27% of the variance in the pupils' mathematics scores. On student-level, the final model showed that six factors predict achievement and explain 50% of the variance in the mathematics scores (pupils' home language, their socio-economic status, the belief that mathematics is important, the language used primarily for learning in the class, the pupils' attitude towards mathematics and the pupils' performance in the English Language test. The results generated and discussed in this chapter prepare the way for the multi-level modelling which follows in Chapter 9.

A description of the technique (PLS) and the technical specifications used in the study was outlined in Chapter 6. The hypothesised school, class and students models were presented in 6.2 in preparation for the analysis. In this chapter the primary focus is on the main results of the analysis on student, class and school level. Firstly, the student level model will be discussed in 8.1, followed by the process of developing a combined school and classroom level model in 8.2. Thereafter the results of the final combined school-classroom level model are given in 8.3 followed by the conclusions drawn from the analysis from all three levels of data in 8.4. The results presented in this chapter seek to address the primary research question of *what effects do factors on school, class and student level have on students' achievement in mathematics*. Whilst the detailed analyses are presented at each level in this chapter, the PLS calculations and more detailed results are given in the appendices.

8.1 RESULTS FROM THE STUDENT-LEVEL ANALYSIS USING PLS

In this section a description of the development of the student-level models is given and the results are discussed. First the process of developing the model is briefly described and thereafter the results for the outer model and inner model are summarised.

8.1.1 Developing a student-level model using PLS

The initial hypothesised model of student level achievement discussed in Chapter 6 includes a large number of factors derived from previous research for inclusion in the PLS model. As mentioned in Chapter 6, there is an intensive process of data preparation prior to being able to run the PLS model. In summary, descriptive statistics were calculated. They were scrutinised for missing values and where there were more than 20% of missing values these variables were removed from further analysis. This is important as misleading results could be generated disallowing the generalisability of the results (Keeves, 1992a). One example of variables being removed was parental education, whilst although considered a very important variable more than 30% of the students had not responded to the level of their father's education and therefore this variable was omitted from further analysis. Where there were fewer than 20% of missing values, these were imputed using the national (e.g. gender) or class (e.g.: language used in the class) mean depending on the variable in question. Factor analysis was applied and a number of components (or factors) were identified as being potential latent variables in the model. Thereafter where possible composites and scales were formed into sum-scores and the reliability of these were checked to make sure they met the Cronbach alpha coefficient of .50, which was considered the minimum score possible to include them in further analysis. The results of the reliability analysis are depicted in Table 8.1 where only those factors meeting this criterion were included and therefore were included in the exploration of the model in addition to single variables.

Table 8.1
*Results of reliability analysis of student level factors**

Factor	Individual variables	Cronbach alpha
School environment	Frequency with which students report something being stolen from them or their friends or being hurt or their friends being hurt (4 items)	.61
Socio-economic status (SES)	Computer, electricity, tap water, tv, CD player, radio, own bedroom, flush toilets, car (9 items)	.75
Importance of English ability	Self, Mother, Friends (3 items)	.75
Teaching methods	Teaching methods (5 items)	.60
Difficulty of maths	The extent to which student reports having difficulty with maths (5 items)	.67
Importance of maths	Extent to which student feels that maths is important (4 items)	.65
Attitude towards maths	How students feel about maths (enjoy, easy, like, job) (4 items)	.59
Student's perception of the importance of mathematics	Extent to which students, Mother, friends think that maths is important (3 items)	.73
Homework	Time spent by student on homework: reading, maths and in general (3 items)	.53

Note: * only those where the Cronbach alpha was above .50 are reported.

Once the reliability analysis was completed, then correlation analysis was applied and a correlation matrix was generated; in Table 8.2, the correlations between all background variables (and not only those from Table 8.1) and the students' mathematics scores are given. The primary purpose of the matrix was to identify variables that had possible relationships with mathematics achievement. However, as correlations merely indicate the strength of relationships between variables and not the direction, this was only a preliminary step for including the variable into the PLS analysis. Correlations with an absolute value above .15 meant that variables were included in the starting model for the PLS analysis.

Table 8.2
Correlation of student background factors with mathematics score

	Pcorr Maths score (above .15)
English test	.63
Calculator	-.15
Desk	-.19
Dictionary	-.22
Age	-.33
Language of Teacher in class	.43
Extra lessons for maths	-.16
Aspiration for further education	.19
Books in the home	.24
Students are quiet in class	-.18
Students are obedient to teacher	-.19
Students need Luck to do well in maths	.28
Students need Hard work to do well in maths	.22
Home language of student	.46
Race of student	.41
Language on radio that students listens to	.45
Students find maths Boring	.25
Number of people living in the home	-.17
Socio Economic Status	.42
Parents living in home	.15
Students self-concept in maths	-.35
The importance of maths for student	.17
Language of learning	.40
Frequency with which student bunks school	-.15
Language of testing	.41
Language spoken by students and teaches in class	.26

As can be seen from Table 8.2, the highest correlations with mathematics achievement scores were found for pupils' English language proficiency ($r = .63$) and background characteristics of the pupils related to language (home language, $r = .46$), the language spoken by the teacher in class ($r = .43$), the language of the radio station most often listened to by the pupil ($r = .45$), race ($r = .41$) and Socio-Economic Status ($r = .42$). There was also quite a high negative correlation between the age of the pupils ($r = -.33$) and their achievement in maths.

The latent and manifest variables that were included in the final PLS analysis are listed in Table 8.3. The results of the PLS final model follow thereafter and are given first for the outer model (8.1.2) and following which the inner model results are presented and discussed (8.1.3).

Table 8.3
Latent and manifest variables included in the final student-level PLS analysis

LATENT VARIABLES	MANIFEST VARIABLES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
MATHSCR	MATH	BSMMAT01	Student mean score on TIMSS-R mathematics test	Score out of 800 points
ENGTEST	TOTSCORE	N/a	Student mean score on English language proficiency test	Score out of 40 points
RACE	RACE_1	POPULAT	Race of student: African, Coloured, Indian, White, Asian	1. African 2. Asian 3. Coloured 4. Indian 5. White
AGE	AGE_1	BSGAGE	Age of student	Number of years
LANG	RALANG_1	RADIO	Language on favourite radio station	1. All other langs 2. Afrikaans 3. English
	HOMELANG	INGUA	Language spoken most often at home	0. Other languages 1. African languages 2. Afrikaans 3. English
HOME	FAMSIZE	BSGHOME	Number of people living in the home	-
	PARENT (COMPOSITE)	GENADU1,2,5,6	Whether students have 2 parents	0 = no 1 = yes
BOOK	BOOKS	BSBGBOOK	Number of books in the home	1. 0-10 2. 11-25 3. 26-100 4. 101-200 5. more than 200
SES	POSSES10 (COMPOSITE)	BSBGPS02,5-14	Computer, electricity, tap water, tv, CD player, radio, own bedroom, flush toilets, car (9 items)	0. no 1. yes
CLASSENV	QUIETCL OBEDCL	BSBMCLS2,3	Class climate items Extent to which the students report that students in their classes are quiet in class, are obedient in class	Scale of (-)1-4 (+) Strongly agree to strongly disagree Scale of (-)1-4 (+) Strongly agree to strongly disagree

Table continued on next page

LATENT VARIABLES	MANIFEST VARIABLES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
LANLEARN	LANLEARN (COMPOSITE)		Extent to which both student and teacher speak language of instruction in maths class	1. language spoken at home if not English/Afrikaans 2. sometimes English/Afrikaans 3. most of the time English/Afrikaans 4. always English/ Afrikaans
MATHIMPT	MATHIMPT (COMPOSITE)	BSBGMIP2 BSBGSIP3 BSBGFIP2	Extent to which students', Mother, friends think that maths is important (3 items)	Scale of (+) 1-4 (-) strongly agree to strongly disagree
ASPIRE	SELFED_1	GENEDSE	Aspirations to education	1. some secondary 2. finished secondary 3. finished technikon 4. some university 5. finished university
ATTEND	ATTEND (COMPOSITE)	BSBGSSKP BSBGFSKP	Extent to which student or students' friends bunk school (2 items)	Scale of (+) 0-4 (-) never, once or twice, three or four times, five or more
SELFCNPT	DIFMATH	MATHMYT_ 1-5	The extent to which student reports having difficulty with maths (5 items)	Scale of (-) 1-4 (+) Strongly agree to strongly disagree
SUCATTRB	LUCK	MATHDOW 2	If the student attributes success to Luck	Scale of (-)1-4 (+) Strongly agree to strongly disagree
ATTITUDE	BOREM	MATHBORE	If student finds maths boring	Scale of (-)1-4 (+) Strongly agree to strongly disagree

8.1.2 Student-level outer model results

Ultimately out of the 22 factors that were hypothesised in chapter 6 to have an effect on achievement, 15 factors remained in the final model. Only the perceived importance of English (*impeng),* teaching methods (*tstyle*), time spent on homework (*homework*) and extra lessons (*lesson*s), gender of the pupil (*sex*), parental education levels (*pareduc*), and learning equipment (*learneq*) were dropped from inclusion in the model. These 15 factors represented 15 latent variables (LVs) and 18 manifest variables (MVs). In case of the language of learning (*lanlearn)*, this was a sum-score calculated prior to inclusion in the model as was importance of mathematics (*impmaths),* the English language proficiency test score *(engtest)* and pupils' self-concept of mathematics (*selfcnpt)*. Most of the LVs were associated with one MV only and are therefore considered unities, that is the LV is formally equal to its single MV in terms of its loading.

A review of the results of the outer model (see Appendix 4) indicates that the weight, loading, communality, redundancy and tolerance are all within the specifications outlined in Chapter 6 (6.3). During the trimming of this model the tolerance coefficient for the LV *lang* (the language spoken at home*)* reached the .50 level. An examination of the data revealed that *lang, SES, lanlearn* and *race* were highly correlated and therefore it was believed that these variables were perhaps causing the high tolerance level. *Race*, as it is an unalterable factor and therefore the least interesting of the variables in question*,* was therefore removed from the equation in the inner model of *mathscr* and observed for its indirect effects via language and SES. After this the tolerance levels for *lang* regained lower levels (namely below .50).

8.1.3 Student-level inner model results

The inner model indicates the relationship between LVs, and four indices reflect the strength of those relationships, namely the Beta, the correlation, the tolerance and the R^2. Although discussed in 6.3, these are briefly summarised here. The *Beta* coefficient provides the index for the strength of one LV on another LV; a beta of .07 is considered significant (Sellin, 1989) in large samples such as this one (more than 8 000 cases). The *correlation* is the product-moment correlation between the independent predictor LV (e.g.: language) and the dependent variable (maths score). Tolerance is the squared multiple correlation between the predictor LV and the remaining predictor LVs in a given model equation and its purpose is to measure the extent of the multicollinearity.

The direct effects (see Beta) and other results of the final PLS student model are presented in Table 8.4 and graphically in Figure 8.1.

As can be seen, six latent variables (*lang, SES, mathimpt, lanlearn, selfcnpt* and *engtest*) predict achievement and explain 50% of the variance in the mathematics scores. The strongest effect is predicted by the students' performance on the English language test (*engtest*) (path coefficient p = 0.39), which may be considered a medium strength relationship (Cohen, 1969) revealing the importance of language proficiency and attainment in mathematics.

Table 8.4
Inner model results of PLS on student-level

Factor	Beta	Correlation with math	Tolerance	R-squared
MATHIMPT				**.02**
Age	-.10	-.11	.0227	
Aspire	.09	-.10	.0227	
LANLEARN				**.24**
Lang	.49	.49	.0000	
BOOK				**.11**
Ses	-.33	-.33	.0000	
CLASSENV				***.07***
Lang	-.19	-.24	.2938	
Race	-.10	-.20	.2938	
ATTEND				***.02***
Age	.08	.09	.0227	
Aspire	-.08	-.10	.0227	
ATTITUDE				**.03**
Age	-15	-.16	.0089	
Attend	-.09	-.10	.0089	
ASPIRE				***.02***
Age	-.15	-.15	.0000	
SELFCNPT				**.18**
Classenv	.14	.20	.0688	
Succattrb	-.25	-.31	.0736	
Attitude	-.28	-.29	.0057	
SUCATTRB				**.10**
Lang	.14	.23	.2176	
SES	.08	.17	.1867	
Classenv	-.21	-.26	.0625	
ENGTEST				**.38**
Age	-.16	-.30	.0697	
Lang	.38	.53	.2212	
Home	-.07	-.22	.0691	
Ses	.18	.42	.2598	
Book	.07	.26	.1216	
Aspire	.10	.19	.0318	
MATHSCR				**.50**
Lang	.18	.52	.4089	
Ses	.10	.41	.2482	
Mathimpt	.11	.17	.0479	
Lanlearn	.08	.40	.2808	
Selfcnpt	-.20	-.35	.1008	
Engtest	.39	.63	.3787	
Mean R squared				**.16**

Therefore, the better pupils performed on the English test *(engtest),* the more likely it was that that they performed better on the mathematics test. Conversely those achieving low scores in English also tended to do so in mathematics. *Selfcnpt* was the next strongest path (p = -0.20) in predicting maths achievement, meaning that those pupils who had a strong self-concept[1] in mathematics were more likely to perform better than those with a poor self-concept regarding mathematics. Language spoken at home (*lang*) was also found to be a relatively strong predictor (p = 0.18) and pupils that spoke the language of the test (English or Afrikaans) were more likely to achieve higher test scores than those not doing so. Pupils who felt that it was important to do well in mathematics (*mathimpt*) (and who reported that their mothers and friends concurred with this) were more likely to achieve higher scores. This was in contrast to those students who believed that doing well in mathematics was unimportant. Finally, students in classes where teachers and students tended to participate in class through the official medium of instruction (*lanlearn*) were also those that tended to perform better in mathematics. Conversely students in classes where this did not happen regularly and where African languages were more frequently used by students asking questions in class or by teachers introducing new or difficult topics in the mathematics class, were also those less likely to achieve high scores.

In addition to the direct effects presented in Table 8.4, Table 8.5 presents the indirect and total effects on achievement. Although all the indirect effects are presented in Table 8.5, only those indirect effects that are greater than or equal to 0.05 (i.e.: contribute approximately 0.25% to the explained variance) are discussed.

[1] A negative score reflects that pupils disagree that mathematics is difficult.

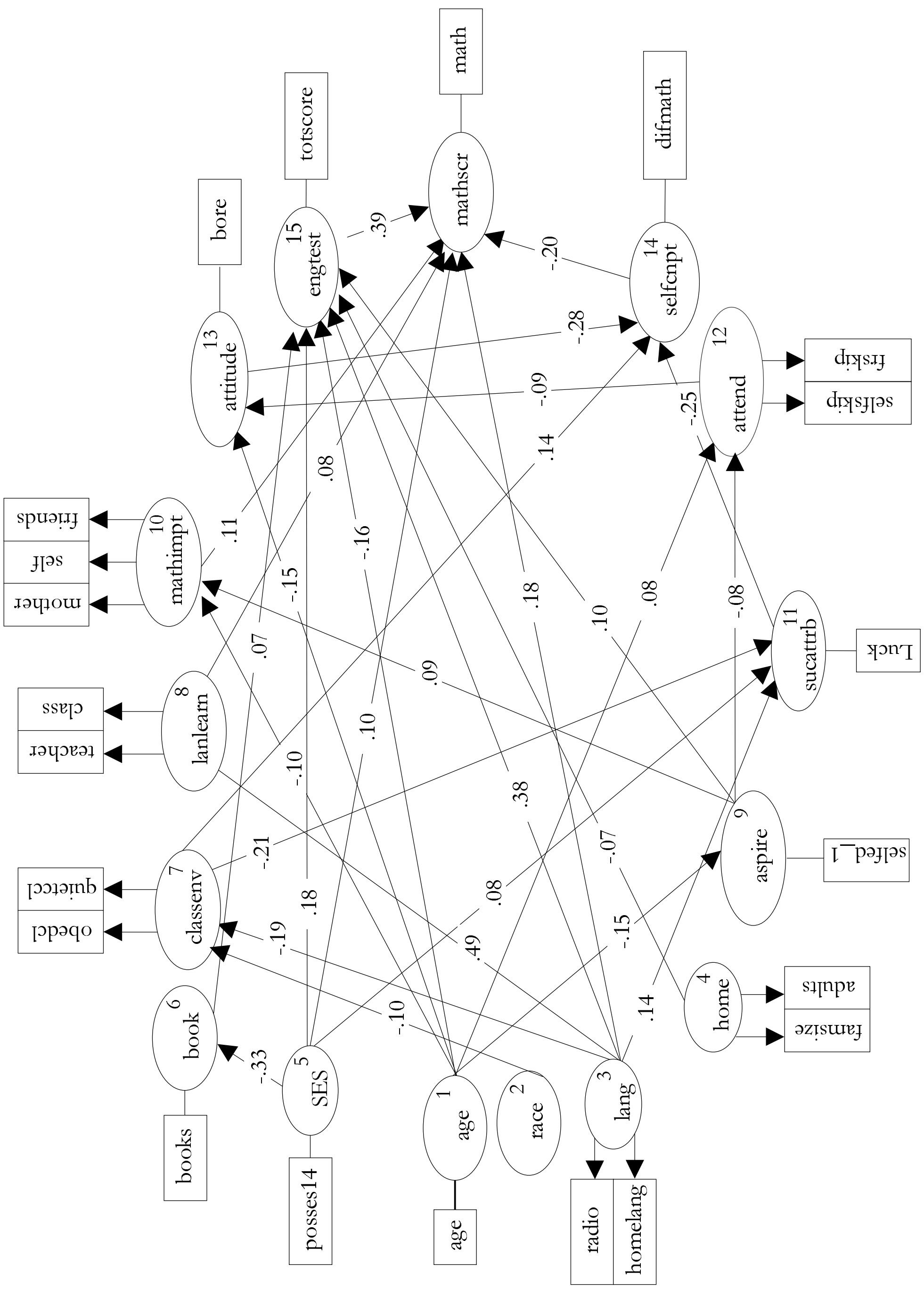


Figure 8.1
Final student level model for achievement in mathematics

Table 8.5
Inner Model effects (direct, indirect and total) for student level factors influencing students' achievement in mathematics

Factor	Direct	Indirect	Total	R-squared
LANLEARN				**.24**
Lang	.49	-	.49	
MATHIMPT				***.20***
Age	-.10	-.01	-.17	
Aspire	-.09	-	-.09	
BOOK				**.11**
Ses	.33	-	.33	
CLASSENV				**.07**
Lang	-.19	-	-.19	
Race	-.10	-	-.10	
ATTEND				**.02**
Age	.08	.01	.09	
ATTITUDE				**.03**
Age	-.14	-.01	-.15	
Aspire	-	.01	.01	
Attend	-.08	-	-.08	
ASPIRE				**.02**
Age	-.15	-	-.15	
SELFCNPT				**.18**
Age	-	.04	.04	
Aspire	-	-.00	-.00	
Lang	-	-.07	-.07	
Race	-	-.02	-.02	
Ses	-	-.02	-.02	
Attend	-	.02	.02	
Classenv	.14	.05	.19	
Succattrb	-.25	-	-.25	
Attitude	-.28	-	-.28	
SUCATTRB				**.10**
Race	-	.02	.02	
Lang	.14	.04	.18	
SES	.08	-	.08	
Classenv	-.21	-	-.21	
ENGTEST				**.38**
Age	-.16	-.01	-.17	
Lang	.38	-	.38	
Home	-.07	-	-.07	
Ses	.18	.02	.20	
Book	.07	-	.07	
Aspire	.10	-	.10	
MATHSCR				**.50**
Age	-	-.09	-.09	
Lang	.18	.21	.38	
Race	-	.00	.00	
Home	-	-.03	-.03	
Ses	.10	.08	.18	
Mathimpt	.11	-	.11	
Lanlearn	.08	-	.08	
Selfcnpt	-.20	-	-.20	
Book	-	.03	.03	
Classenv	-	-.04	-.04	
Attend	-	-.00	-.00	
Attitude	-	.06	.06	
Aspire	-	.05	.05	
Sucattrb	-	.05	.05	
Engtest	.39	-	.39	
Mean R squared				**.16**

The indirect effects reveal the strength of the relationship of a variable for example *attitude* (p = 0.06) on a variable such as the mathematics score (*mathscr*). However the effect is caused by the relationship of attitude to a variable such as *selfcnpt* (p = -0.28*)*, which in turn had a direct strong effect (p = -0.20) on mathematics. Therefore the relationship between *attitude* and the *mathscr* was not a direct one, but the effect of *attitude* on the *mathscr* is described as having an indirect effect. In Table 8.5, the indirect effects on mathematics achievement can be observed. *Age* (p = -0.09), *attitude* (p = 0.06)*, aspire* (p = 0.05) *and sucattrb* (p = 0.05) all have small indirect effects only, meaning that their influence on mathematics achievement is reflected via other variables. However, in addition to having direct effects on achievement, *lang* (p = 0.21) and *SES* (p = 0.08) have relatively strong indirect effects on achievement (and *lang* has a stronger indirect effect than direct effect). This provides one with an indication of the pervasive influence of these two variables on the student level. *lang* had an indirect effect on mathematics not only through its strong effect (p = 0.49) on *lanlearn*, but also through its direct effect (p = -0.19) on *classenv*. *Lang* also had an indirect effect (p = -0.07) on *selfcnpt,* which had a direct effect (p = -0.20) on mathematics.

In conclusion, it would appear that a number of factors are closely related such as *lang, engtest, SES* and *race* and that this was reflected in the final model. The pervasive influence of the language-related factors (*engtest*, *lang* and *lanlearn*) was seen and especially the strength of the effect of *engtest* on the mathematics achievement score. Also interesting to see was the strength of the factor related to pupils' *selfconcept* in mathematics. It remains to be seen from the multi-level analysis (Chapter 9) how these factors fare when inserted into a combined model with factors on class and school level.

8.2 TOWARDS DEVELOPING A SCHOOL-LEVEL MODEL IN PLS

As has been previously mentioned, due to the fact that only one class per school was tested, a combined school-class model had to be developed. However, because of the technical restrictions of the number of latent variables that could be included in PLS, an initial independent exploration of both the school-level variables and the classroom-level variables was done prior to combining the two levels of data to achieve a combined model. In this section a description of the building of the school and classroom level models is given and the results are discussed. First the school level variables are included in a separate model (8.2.1) and then the separate classroom level model is described (in 8.2.2) and the results are summarised.

8.2.1 Analysis of the school-level only factors using PLS

A review of the school principal's questionnaire revealed that almost all the items could be categorised under the components *school quality, teachers' characteristics, student characteristics,* and *curriculum quality* in the conceptual framework described in Chapter 5. After examining the descriptive statistics combined with the literature review, the following factors were identified for further analysis: *human resources, selection of students, learning environment, principals' activities, parents involvement, school enrolment, repeaters, average grade 8 class size, time on task, grade size, location of the school, retention of teaching staff, limitations*, and *autonomy*. A description of each of these factors may be found in Appendix 5.

First the descriptive statistics for the school principal's data were examined for missing values and, once these had been replaced, factor analysis was conducted and the reliability analysis was undertaken. In addition to the single variables that were included in the PLS analysis, a number of composite variables were included on the basis of the results of the factor and reliability analysis. The factors given in the Table 8.6 below are those that had a Cronbach alpha coefficient of at least .50, which was the criterion for inclusion in the PLS starting model.

Table 8.6
Results of reliability analysis of school-level only factors

Factor	Individual variables	Cronbach alpha
Selection	Admission procedures (13 items)	.75
Learning environment	Frequency of negative behaviour (9 items)	.87
Principals' activities	Hours spent by principal on selected activities at school (14 items)	.51
Parental involvement	Schools' expectations of the extent of parents involvement in schools' activities (6 items)	.74
Limitations	Shortages of general resources (5 items)	.75
	Shortages of maths related resources (6 items)	.87
Autonomy	Responsibility for Decision-making in school (14 items)	.65
	Stakeholders influence of implemented curriculum (4 items)	.85

After the reliability of all the constructs was tested, a correlation matrix was analysed. Each of the constructs and the other previously identified singletons (indicated by one item) were examined in relation to the mean mathematics scores. The results of this analysis are found in Table 8.7. Of the 17 individual variables (clustered into 13 factors), 10 of these were found with a absolute value of the coefficient higher than 0.15, which was taken as the cut-off point for inclusion in further analysis and as indications for potential direct paths to mathematics achievement.

Table 8.7
Correlation of school background factors with mathematics score meeting the criterion

Factor	Individual variables	Pcorr. Math score
Human resources	Number of teachers in school	.39 **
Learning environment	Absenteeism	-.20 **
First language	Number of students in the tested class whose first language is the same as the medium of instruction	.58 **
School enrolment	Number of students enrolled in school	.28 **
Repeaters	Number of students repeating grade 8	-.20 **
Class size	Average number of students in grade 8 classes	-.22 **
Community	Urban-rural community where school is located	.36 **
Limitations	Shortages of general resources (5 items)	-.18 *
	Shortages of maths related resources (6 items)	-.19 **
Autonomy	Influence of teacher union on curriculum	-.22 **

Notes: * significant at the 0.05 level, ** significant at the 0.01 level.

No correlation with achievement was found for the *selection* of students into schools, the reported frequency of negative behaviour (under *learning environment)*, retention of teaching staff and stakeholders' influencing the curriculum (under *autonomy*). Furthermore, responsibility for decision-making in the school (under *autonomy*) and parental involvement revealed low correlations (-.10 and .13 only) with mathematics achievement (and therefore are not included in Table 8.7*)*. The most highly correlated items with maths achievement were first language speaking students and the community where the school is located. The higher the proportion of first language speakers, in the class being tested, the higher the mean achievement score of that particular school's pupils. As this variable is also associated with socio-economic group status in South Africa this finding is to be expected. Historically, students speaking English or Afrikaans are generally expected to come from more advantaged backgrounds than the majority of students speaking African languages at home. In addition to that, schools attended by the majority of first language speakers are considered privileged in their resources and generally have better facilities, equipment and more highly qualified teachers. It is important to note here that the exception to this would be the schools which previously contained only Indian (typically having English as their home language and sometimes in addition to Indian languages) and coloured (of mixed race) students (having either English and Afrikaans as a home language). These schools would also have been disadvantaged under the old dispensation having poorer resources than former White schools, but generally slightly better than those of African schools.

The correlation between community and maths achievement indicates that the schools in the more urban areas tend to produce better results than in rural areas. Again, this is perhaps not surprising as urban schools, on the whole, have better resources and often attract students from more privileged backgrounds than rural students.

As for the school-level analysis a path diagram was drawn prior to building a model using PLS and this hypothesised model was described in Chapter 6. This was done conceptually on the basis of what school-level factors could be expected (from the literature and knowledge of the context) to influence students' achievement in mathematics. The starting model for PLS was implemented by reviewing the hypothesised model and looking at the results of the analysis described previously in this section. Unlike the student level model where the large sample of 8 141 students permitted the usage of a lower beta coefficient of .07 as a criterion for trimming the model, a beta of .10 (recommended by Sellin, 1995) was used for the smaller sample of 189 schools. The selection of variables included in the final school-level model is given in Table 8.8. These first analysis steps result in some differences between the hypothesised model and the variables included in the final model. For instance, after examining the data, it was decided to use the teacher:pupil ratio (*teachrat*) in place of the number of teachers (human resources). The learning environment concept in the hypothesised model was divided into two variables absenteeism (*absent*) and criminal behaviour (*crime*) as these two were clearly distinguishable issues. The strength of the language variable at student-level (see student-level model in 8.1.3) resulted in the belief that this variable should also be examined on school level and therefore was included into the final school-level model.

Table 8.8
Latent and manifest variables on school-level and their descriptors included in the final PLS model

LATENT VARIABLES	MANIFEST VARIABLES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
COMMUNITY	SCCOMM_1	Schlcomm2	the location of the school: in isolated area or village, rural town, outskirts of a city and city centre	1. geographically isolated area 2. village or rural (farm) area 3. on outskirts of town or city 4. close to centre of town or city .
SCHOOL	SCHSIZE	bcdgtenr	the number of students enrolled at the school	Actual number
CLASS	CLASSIZE	bcbgusiz	the average number of students across the grade 8 classes)	Actual number
FIRSLANG	F_LANG	bsbghome	the number of students whose home language was the same as the medium of instruction in the school	1. African languages 2. English or Afrikaans
REPEATER	REPEAT	bcdgutrt	the percentage of students repeating grade 8	Actual number
TEACHAT	TSTRATIO	bcbgftte bcggptte	number of full-time teachers in the school number of part-time/ full-time equivalent teachers in the school number of pupils in school	Actual number Actual number Actual number
RESOURCE	RESOURG	Genst01-05	shortages of general facilities and learning equipment	1. none 2. a little 3. some 4. a lot
CRIME	CRIMEF	Genuf01-18	The frequency of negative behaviour and the	1. "never" 2. "rarely" 3. "monthly" 4. "weekly" 5. "daily"
ABSENT	ABSENT_1	Bcbgabst	percentage of students absent on an given day	% of students
PARENT	PAREN	Genep01-05,9-10	schools' expectations of parents' involvement at school	0. no 1. yes
UNION	UNINF_15	Genif15	The extent to which the teacher unions influence the curriculum implemented at the school	1. none 2. a little 3. some 4. a lot

8.2.2 School-level only outer model

Ultimately, at this stage of the school-level model only unities were entered into the outer model, meaning that a latent variable was reflected by a single manifest variable. Out of the 13 factors that were hypothesised in Chapter 6 to have an effect on achievement, only seven of the original factors remained in the final model namely, location (*community*), school enrolment (*school*), limitations (*resources*) repeaters (*repeater*), human resources (*teachrat*), class size (*class*), influence of teacher unions (*union*). As explained earlier first language speakers (*firslang*) (an aggregated student level variable) was added later and had not been included in the hypothesised model. Principals' activities, selection, grade size, and retention were not included in the final model as they failed to meet the minimum criteria outlined in chapter 6. During the development of the model (see Table 8.8 for all the factors that were included in the PLS model), three factors were eliminated namely, *absent, parent* and *crime* as they did not meet the criteria as described in Chapter 6. The final eight included factors represented 8 latent variables, which in turn represented 8 manifest variables. In case of *resources*, this was a sum-score calculated prior to inclusion in the model comprising one scale of five items in total.
The outer model results (see appendix 6) indicate that the weight, loading, communality, redundancy and tolerance are all within the specifications outlined in 6.3.

8.2.3 School-level only inner model

Table 8.9 shows that 62% of the variance in the student's achievement in mathematics (Math) can be explained by the variables *community*, *union* and *first language*. The results indicate that the students from schools in urban communities (*communit* p = 0.18) and students from schools where the students speak the medium of instruction at home (*firslang* p = 0.66) are more likely to do better in mathematics. On the other hand, students in schools where teacher unions' (*union* p = -0.17) are influential in determining what is taught are likely to perform worse in mathematics than students in schools where this is not the case.

Although often quoted in the literature as influencing achievement, the average class size in Grade 8 as seen in the model (Figure 8.2) has a very weak relationship (-0.08 and not significantly different from zero given the small sample) with the mathematics score and was only included for illustrative purposes in the model.

Few indirect effects on mathematics were found (see Table 8.10) and these of *communit, firslang* and *school* were very small (0.01). In addition to the direct effect that the location of the school (*communit)* (p = -0.19) had on the size of the class (*class*), there was also an indirect effect (p = 0.07) via the size of the school.

Table 8.9
Inner model results of PLS on school level

Factor	Beta	Correlation	Tolerance	R-squared
Repeater				.69
Teachrat	.83	.83	.0000	
School				.21
Communit	.45	.45	.0000	
Class				.12
Communit	-.19	-.21	.2628	
Resource	.16	.20	.0464	
Firslang	-.18	-.22	.1025	
School	.16	.01	.2193	
Math				.62
Communi	.18	.41	.1281	
Union	-.17	-.25	.0275	
Firslang	.66	.74	.1126	
Class	*-.08*	*-.26*	*.0708*	
Mean R-squared				**.41**

Table 8.10
Inner model effects (direct, indirect and total) for school level-only factors influencing pupils' achievement in mathematics

Factor	Direct	Indirect	Total	R-squared
Repeater				.69
Teachrat	.83	-	.83	
School				.21
Communit	.45	-	.45	
Class				.12
Communit	-.19	.07	-.12	
Resource	.16	-	.16	
Firslang	-.18	-	-.18	
School	.16	-	.16	
Math				.62
Communi	.18	.01	.19	
Union	-.17	-	-.17	
Firslang	.66	.01	.67	
School	-	-.01	-.01	
Class	*-.08*	-	*-.08*	
Mean R-squared				**.41**

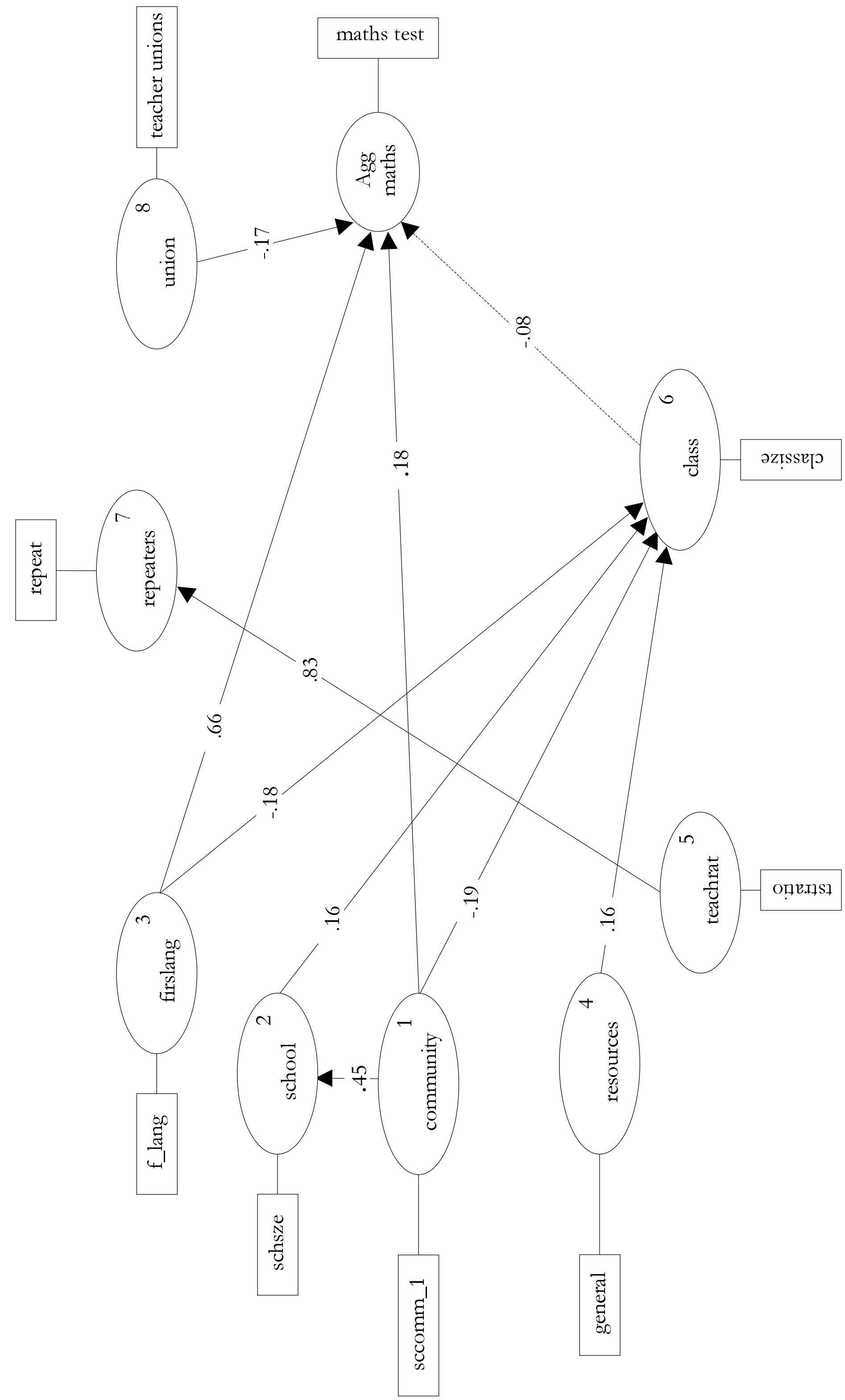


Figure 8.2
Final model of school-level factors only

As can be seen in the model (see Figure 8.2), the number of repeaters (*repeater*) at the school is greatly influenced by the student:teacher ratio (*teachrat*) (p = 0.83) with 69% of the variance being explained by this variable alone. Repeaters are most likely to come from schools where the student:teacher ratio is high and therefore teachers are dealing with larger numbers. The school size (*school*) is influenced by the location it is in (*communit*) (p = 0.45) and larger schools are found in more urban settings. Class size (*class*) is influenced by a number of factors. Those found include the location/community (*communit*) (p = -0.19), the resources in the school (*resource*), whether there are first language speakers (*firslang*) (p =-0.18) and the size of the school (*school*) (p = 0.16). The variance explained (seen by the R-squared coefficient in Table 8.9 and 8.10) is low (0.12) and only just meets the criteria of .10 recommended by Sellin (1995) for smaller samples (such as 189). The larger classes are more likely to be found in rural communities, where there are greater shortages of general resources, where most of the students speak African languages at home and where the schools have high enrolment numbers.

Finally, the percentage of variance explained by the model overall is 41%, which in itself is higher than a recent study conducted using data from another developing country, Indonesia (Mohandas, 1999), which managed to explain 60% of the variance in the mathematics score, but only 26% of the variance explained by the model.

8.2.4 Results of the classroom-level only analysis

In addition to the school factors, the study sought explanations for pupils' achievement in mathematics on teacher or classroom-level. Like the school level factors, the large number of potentially influential factors meant that the classroom level factors were also first explored separately.

Almost all of the hypothesised items in the mathematics teacher questionnaire could be categorised under the components *teaching quality, instructional quality and curriculum quality* in the conceptual framework described in Chapter 5. After examining the univariates combined with the literature review, the following factors were identified for further analysis: *teacher load, attitudes to teaching, teaching style, sex, qualifications, experience of teacher, home language of teacher, age, books, teachers' confidence, teachers' beliefs, limitations, resources, topic coverage* and *class size*. A description of each of these factors may be found in Table. 8.13.

Similar preparatory steps to those described in section 8.2.1 were taken in order to prepare the teacher data for model building (i.e. descriptives, frequencies, replacing the missing values, the correlation matrix, factor analysis and reliability analysis were conducted for each variable in the model). In this section, the reliability analysis is described followed by a summary of the results of the correlational analysis and thereafter a description of developing and exploring the model and finally the results of the PLS analysis.

A number of these classroom factors were composites developed through a process of factor analysis (including principal component analysis) and reliability analysis. The reliability coefficients are given in Table 8.11 for each of the constructs described previously. As with the student-level and school level analyses, if the Cronbach alpha coefficient was higher than .50, it was considered suitable for inclusion in the further analysis.

Table 8.11
Results of reliability analysis for classroom-level variables

Factor	**Individual variables**	**Cronbach alpha**
Teaching style	Class activities – higher order skills (4 items)	.65
	Class activities (3 items)	.40
	% of time spent on teaching activities (6 items)	.84
Teacher beliefs	Teachers' beliefs about students' success in mathematics (5 items)	.65
	Teachers' beliefs about mathematics in general (6 items)	.68
Limitations	Obstacles to teachers' ability to teach mathematics – pupil related (7 items)	.69
	Obstacles to teachers' ability to teach mathematics - teacher related (7 items)	.84

Ultimately only three factors were developed as composites, namely *teaching style, teachers' beliefs* and *limitations*. One of the scales under the factor *teacher beliefs,* namely *about mathematics in general* was a complex composite where six items[2] were combined.

[2] These were the following: that mathematics is primarily a formal way of representing the real world; that mathematics is primarily a practical and structured guide for addressing real situations; if students are having difficulty an effective approach is to given them more practice by themselves during the class; that more than one representation (picture, concrete material, symbol set etc) should be used in teaching a maths topic; the mathematics should be learned as sets of algorithms or rules that cover all possibilities; and that basic computational skills on the part of the teacher are sufficient for teaching secondary school maths.

Each item represented an orientation, for example:

- The 'inductive mathematical orientation' is operationalised in 'mathematics is primarily a formal way of representing the real world'.
- The 'inductive mathematical technological orientation' in 'mathematics is primarily a practical and structural guide for addressing real situations.

Although all these orientations are conceptually different, it appeared in the factor analysis of the teacher variables that all six items clearly formed a factor 'teacher beliefs about mathematics'. Apparently teachers value various orientations in mathematics and their belief about the importance of one is related to the others. Therefore 'teachers beliefs' can be interpreted as a factor indicating the importance teachers adhere to mathematics as a discipline in its own right.

After the reliability of all the constructs was tested, a correlation matrix was analysed. Each of the constructs and the other previously identified factors that are single variables were explored in relation to the mean mathematics scores and between variables. The results of this analysis are given in Table 8.12, for those factors where the absolute value of correlation coefficients exceeded .15.

Table 8.12 lists the 20 variables out of the 39 individual variables (clustered into 15 factors) that were found with an absolute value of the correlation coefficient equal to or higher than 0.15, which was taken as the cut off point for inclusion in further analysis and as indications for direct paths to mathematics achievement. The highest correlations to mathematics achievement were the perceptions of the teacher with regard to how society appreciates the work of the teacher. However these were negative correlations meaning that the more the teachers reported feeling appreciated, the lower the score of the pupils. There was also a high correlation regarding teachers beliefs about mathematics in general (r = -0.42) indicating that the stronger their beliefs the lower the pupils' maths scores. A strong correlation (r = -0.29) was found with class size meaning that the larger the class of tested pupils, the lower the scores in mathematics.

Table 8.12
Correlation of classroom factors with mathematics score

Factor	Individual variables	Pcorr. Math score
Teaching style	Teaching methods and classroom organisation (2 items)	-.22 **
	% of time spent on teaching activities (6 items)	-.22 **
	% of time spent on administrative activities	-.19 **
Teacher load	Teaching time	.28 **
	All time spent on activities related to work	.30 **
Attitudes to teaching	Perception where society appreciates work of teacher	-.55 **
	Perception whether pupils appreciate work of teacher	-.42 **
	Teacher preparation outside school hours – lesson planning alone by teacher	.28 **
Sex	Gender of teacher	-.18 *
Qualifications	Highest level of qualification	.23 **
	BA in mathematics education	.-18 *
	Starting preservice education in secondary education	.19 **
Experience of teacher	Years of teaching	.17 *
Books	No of books in the home	.24 **
Teachers' beliefs	Teachers' beliefs about students' success in mathematics	-.16 *
	Teachers opinions about formulas and procedures in learning mathematics	-.15 **
	Teachers' beliefs about mathematics in general	-.42 **
Limitations	Obstacles to teachers' ability to teach mathematics - teacher related	.-18
Resources	Computers outside of classroom in school	.17 *
Class size	Number of pupils in mathematics classes that were tested	-.29 **

Note: * significant at the 0.05 level, ** highly significant at the 0.01 level.

The more time teachers spent on teaching, the higher the achievement score (r =0.28). Likewise the more time teachers spent on their activities related to teaching, the higher the mathematics mean score (r = 0.30). Similarly the greater the frequency of reported time spent of preparation for lessons, the higher pupils' scores were in mathematics (r = 0.28). The level of teachers' qualification was correlated with achievement, as was the number of books in the teachers' home (r = 0.24). No correlation was found between time on task, teaching as a first choice, changing career, teachers liking and understanding pupils, availability of calculators, teachers' confidence in their content knowledge and pupils' achievement in mathematics.

A hypothesised path model was compiled conceptually on the basis of what classroom-level factors could be expected (from the literature and knowledge of the context) to influence students' achievement in mathematics (see Chapter 6). It is hypothesised that a number of classroom factors influence achievement directly (such as the class size, teacher qualifications, time on task**,** amongst others) whilst others also influence the achievement indirectly. Once the correlational analysis was completed, the factors were selected for inclusion into an initial model (a reduced hypothesised model). This initial model was explored using partial least squares analysis and the first stage involved drawing the path diagram and thereafter systematically trimming the model. The same criteria were applied as for the school-level model.

Table 8.13
Latent and manifest variables included in the final classroom-level PLS model

Latent variables	Manifest variables	TIMSS-R Variables	Description of factor	Scoring
GENDER	SEXTEACH	Btbgsex	Gender of teacher	1. male 2. female
TEDUC	EDUCATN	Geneduc	Highest level of qualification	1. did not complete sec school 2. secondary school 3. BA or equiv 4. MA/PHD
EXPER	YRSTEACH	Btbgtaug	Years of teaching	No. of years
TBACKGR	BOOKHOME	Btbgbook	No of books in the home	1. 0-10 2. 11-25 3. 26-100 4. 101-200 5. >200
CLASSIZE	TESTSIZE	Btdmtoen	Number of pupils in mathematics classes that were tested	No. of pupils
RESOURCE	COMPOTH	Btbmcom2	Computers outside of classroom in school	1. never or almost never 2. some lessons 3. most lessons 4. every lesson

Table continued on next page

Latent variables	Manifest variables	TIMSS-R variables	Description of factor	Scoring
LIMIT	LIMSTUD	Btbmlm01-5, 15-16	Obstacles to teachers' ability to teach mathematics – pupil related	0. not at all 1. a little 2. quite a lot 3. a great deal
	LIMTEACH	Btbmlm08-9, 11-14	Obstacles to teachers' ability to teach mathematics - teacher related	0. not at all 1. a little 2. quite a lot 3. a great deal
TLOAD	TOTTIME	btbgtotl	Teaching time	No. of hrs
	ALLTIME	Btbgalto	All time spent on activities related to work	No. of hrs
DEDIC	PLANLESN	Btbgact3	Teacher preparation outside school hours – less planning alone by teacher	0. = none 1. <1hour 2. 1-2 hrs 3. 3-4 hrs 4. >4hrs
ACTIV	TEACACT		% of time spent on teaching activities	% of time
TSTYLE	PAIRCLAS	Btbmles5 Btbmles6	Teaching methods and classroom organisation	1. never or almost never 2. some lessons 3. most lessons 4. every lesson
BELIEFS	TBMATH	Btbmagr2-4, 6-8	Teachers' beliefs about mathematics in general	1. strongly disagree 2. disagree 3. agree 4. strongly agree
STSUCC	STUDSUCC	Btbmimp2-6	Teachers' beliefs about student success	1. strongly disagree 2. disagree 3. agree 4. strongly agree
ATTITUDE	APPREC	Gensoap	Perception where society appreciates work of teacher	0. = no 1. = yes
		Genstap	Perception whether pupils appreciate work of teacher	0. = no 1. = yes

8.2.5 Classroom-level only outer model

Ultimately 14 factors were included in the model. The discrepancy between the hypothesised and final model occurred due to the results during the exploration of the possible factors, because of the number of teacher/class level factors that were found to correlate with achievement, it was decided that only teacher variables would be included in the final model and that the aggregated student level variables would only be inserted in the combined model (see 8.3). The variables included in the final model (see Table 8.13) were teaching load (*tload*), attitude (*attitude*), dedication (*dedic*), activities (*activ*), teaching style (*tstyle*), teachers' background (*tbackgr*), gender (*gender*), teachers' education (*teduc*), experience (*exper*), resource (*resource*), class size (*classize*), beliefs about mathematics (*beliefs*), beliefs about student success *(stsucc)* and limitations (*limit*). Of these latent variables, only three had more than one manifest variable, namely *tload* (with manifest variables *tottime* and *alltime*), *limit* (*limstud* and *limteach*) and *attitude* (*bsbgsoap* and *bsbgstap*). All the other variables were unities.

The results of the outer model (see appendix 7) revealed that the weight, loading, communality, redundancy and tolerance are within the criteria specified in Chapter 6.

8.2.6 Classroom-level only inner model

The inner model results are given in Table 8.14 that specifies the relationship between the latent variables.

Table 8.14
Inner model results of PLS on classroom level

Factor	Beta	Correlation	Tolerance	R-squared
ATTITUDE				**.35**
TLOAD	-.27	-.35	.06	
TBACKGR	*-.09*	*-.20*	*.08*	
TEDUC	-.14	-.28	.10	
CLASSIZE	.14	.22	.05	
BELIEFS	.32	.41	.11	
LIMIT	-.21	-.17	.01	
DEDIC				**.06**
ATTITUDE	-.24	-.24	.00	
STSUCC				
EXPER	.16	.11	.03	
BELIEFS	.27	.25	.03	
ACTIV				**.08**
TLOAD	-.14	-.18	.03	
TEDUC	-.10	-.19	.07	
BELIEFS	.28	.32	.07	
TSTYLE				**.10**
EXPER	.11	.06	.03	
BELIEFS	.32	.34	.03	
BELIEFS				**.12**
TLOAD	*-.09*	*-.13*		
GENDER	*.09*	*.08*	*.01*	
EXPER	-.21	-.18	.03	
TEDUC	-.26	-.24	.04	
LIMIT	*.08*	*.06*	*.02*	
MATHSCR				**.46**
TLOAD	.19	.37	.16	
TBACKGR	*.08*	*.24*	*.08*	
GENDER	-.11	-.18	.03	
RESOURCE	.11	.16	.05	
CLASSIZE	-.13	-.29	.09	
BELIEFS	-.23	-.44	.20	
ATTITUDE	-.29	-.53	.31	
DEDIC	.10	.28	.12	
Mean R-squared				**.22**

Note: Factors in italics signify that the path coefficients fall below the required p =.10 criterion.

The results in Table 8.14 (also represented in Figure 8.3) shows that 46% of the variance in the pupils' achievement in mathematics (*mathscr*) can be explained by the variables teaching load *(tload),* resources *(resource)*, class size *(classize),* teachers' beliefs *(beliefs),* and teachers' attitudes *(attitude), gender (gender),* books in teachers' homes *(tbackgr)* and lesson preparation *(dedic).* The strongest predictor of achievement on classroom level is *attitude* a measure of the teachers' attitudes towards their professional status. Teachers who believed that they are appreciated by society and by their pupils are also those whose pupils are more likely to achieve lower scores. This unexpected outcome cannot easily be explained.

The results also indicate teachers' beliefs and their workloads contribute significantly to the explanation of the variance in mathematics achievement at classroom level ($p = -.23$ and $p = .19$ respectively). This means that pupils in classes where the teachers' beliefs about mathematics are relatively stronger achieve lower scores for mathematics. Another relatively strong predictor is *tload.* Seemingly incongruously, pupils whose teachers report having heavier workloads, achieve higher scores. This may be an indicator of the fact that the better teachers are more heavily loaded because of their capability. Furthermore, the weaker predictors revealed that pupils in larger classes (*classize*) ($p = -.13$) tend to achieve lower scores, whilst those where there were better resources (*resource*) ($p = 0.11$) tend to attain higher scores in mathematics, as did pupils in classes taught by male teachers (*gender*) ($p = -0.11$). Pupils whose teachers spent more time planning their mathematics lessons (*dedic*) ($p = 0.10$) also achieved higher scores in the mathematics test. Finally, it appears that the number of books in the teachers' home (*tbackgr*) ($p = 0.08$) has a slight effect on the performance of their pupils.

A closer examination (in Table 8.14) of the strongest predictor of mathematics achievement, *attitude*, revealed that 35% of the variance in *attitude* was explained by six factors. These were teaching load (*tload*) ($p = -0.27$), teacher background (*tbackgr*) ($p = -0.09$), teachers' education (*teduc*) ($p = -0.14$), class size (*classize*) ($p = 0.14$), beliefs (*beliefs*) ($p = 0.34$) and limitations (*limits*) ($p = -0.21$). Teachers with strong beliefs about mathematics, who had a lighter workload, who did not experience obstacles from fellow teachers, worked in larger classes and had a lower qualification tended to have strong feelings about being appreciated by society and their pupils. However, as was seen earlier these teachers' pupils were also more likely to attain lower scores in mathematics ($p = -0.29$).

Beliefs was found to be the next strongest predictor of mathematics achievement, but only 12% of the variance across the scores on teachers' beliefs could be explained by the inclusion of five factors (*tload, gender, exper, teduc* and *limit*). Teachers with the strongest beliefs tend to have lower levels of education (p = -0.26), less experience (p = -0.21), be female teachers (p = 0.09), have lighter teaching loads (p = -0.09) and to report more obstacles to their teaching ability than others (p = 0.08). As was also seen earlier, the pupils of these teachers were also likely to achieve lower scores.

Further examination of other factors revealed some interesting results. Teachers who reported spending more time on lesson preparation (*dedic*) were also those who were more likely to be negative about their status and feel less appreciated by society and their pupils. Teachers who had strong feelings about what it took for pupils to be successful were those more likely to have been teaching for a longer time and were those that had strong beliefs about mathematics. Teachers who reported spending more time on teaching activities were those who tended to have a lighter teaching load, those with less education and those with stronger beliefs about mathematics. The implication of this latter finding could possibly indicate over-reporting of the percentage of time spent on their activities and could possibly have resulted in the factor (*activ*) not having an effect on achievement.

In addition to the direct effects, it is also important to take note of the indirect effects of the factors on achievement especially. These can be seen in Table 8.15 as well as the total effects. With regard to mathematics achievement, several variables have an indirect effect. The largest of these are *teduc* (p = 0.13), *tload*, (p = 0.11) and *beliefs* (p = 0.10) of which *tload* and *beliefs* already had direct effects. The indirect effect of *tload* for example is the result of its direct effects on attitude and beliefs, which in turn both had significant effects on achievement. Therefore in addition to the fact that teachers with heavier loads tended to produce pupils with better mathematics achievement, they also tended to have stronger negative feelings about their status (*attitude*) and to a much lesser effect have weaker beliefs (*beliefs*) regarding mathematics. As the latter two factors have strong effects on achievement, the *tload* has both an indirect and direct effect on achievement. The indirect effect of *beliefs* is a result of its strong direct effect on attitude, which in turn had a strong direct effect on achievement. This means that teachers with strong beliefs about mathematics tended to have a more positive attitude towards their own status, which in turn had a negative effect on achievement.

Table 8.15
Inner model effects (direct, indirect and total) on classroom level influencing mathematics achievement

Factor	Direct	Indirect	Total	R-squared
ATTITUDE				.35
TLOAD	-.27	-.03	-.29*	
TBACKGR	*-.09*	-	*-.09*	
GENDER	-	.03	.03	
TEDUC	-.14	-.08	-.22	
EXPER	-	-.68	-.68	
CLASSIZE	.14	-	.14	
BELIEFS	.32	-	.32	
LIMIT	-.21	.03	-.18	
BELIEFS	.32	-	.32	
STSUCC				.08
EXPER	.16	-.06	.10	
LIMIT	-	.02	.02	
BELIEFS	.27	-	.27	
ACTIV				.13
TLOAD	-.14	-.02	-.16	
GENDER	-	.03	.03	
TEDUC	-.10	-.7	-.17	
EXPER	-	-.06	-.06	
LIMIT	-	.02	.02	
BELIEFS	.28	-	.28	
TSTYLE				.10
TLOAD	-	-.03	-.03	
GENDER	-	.03	.03	
TEDUC	*-.08*	-	*-.08*	
EXPER	.11	-.07	.05*	
LIMIT	-	.03	.03	
BELIEFS	.31	-	.31	
DEDIC				.06
TLOAD	-	.07	.07	
TBACKGR	-	.02	.02	
GENDER	-	-.01	-.01	
TEDUC	-	.05	.05	
EXPER	-	.02	.02	
CLASSIZE	-	-.03	-.03	
LIMIT	-	.04	.04	
BELIEFS	-	-.08	-.08	
ATTITUDE	-.24	-	-.24	

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Factor	Direct	Indirect	Total	R-squared
BELIEFS				.12
TLOAD	*-.09*	-	*-.09*	
GENDER	*.09*	-	*.09*	
EXPER	-.21	-	-.21	
TEDUC	-.26	-	-.26	
LIMIT	*.08*	-	*.08*	
MATHSCR				.46
TLOAD	.19	.11	.30	
TBACKGR	*.08*	*.03*	*.11*	
GENDER	-.11	-.03	-.14	
TEDUC	-	.13	.13	
EXPER	-	.07	.07	
RESOURCE	.11	-.	.11	
CLASSIZE	-.13	-.05	-.18	
LIMIT	-	.04	.04	
BELIEFS	-.23	-.10	-.33	
DEDIC	.10	-	.10	
ATTITUDE	-.30	-.02	-.32	
Mean R-squared				**.22**

Note: * figures rounded off and therefore do not always add up exactly.
Factors in italics signify that the direct path coefficients fall below the required p =.10 criterion.

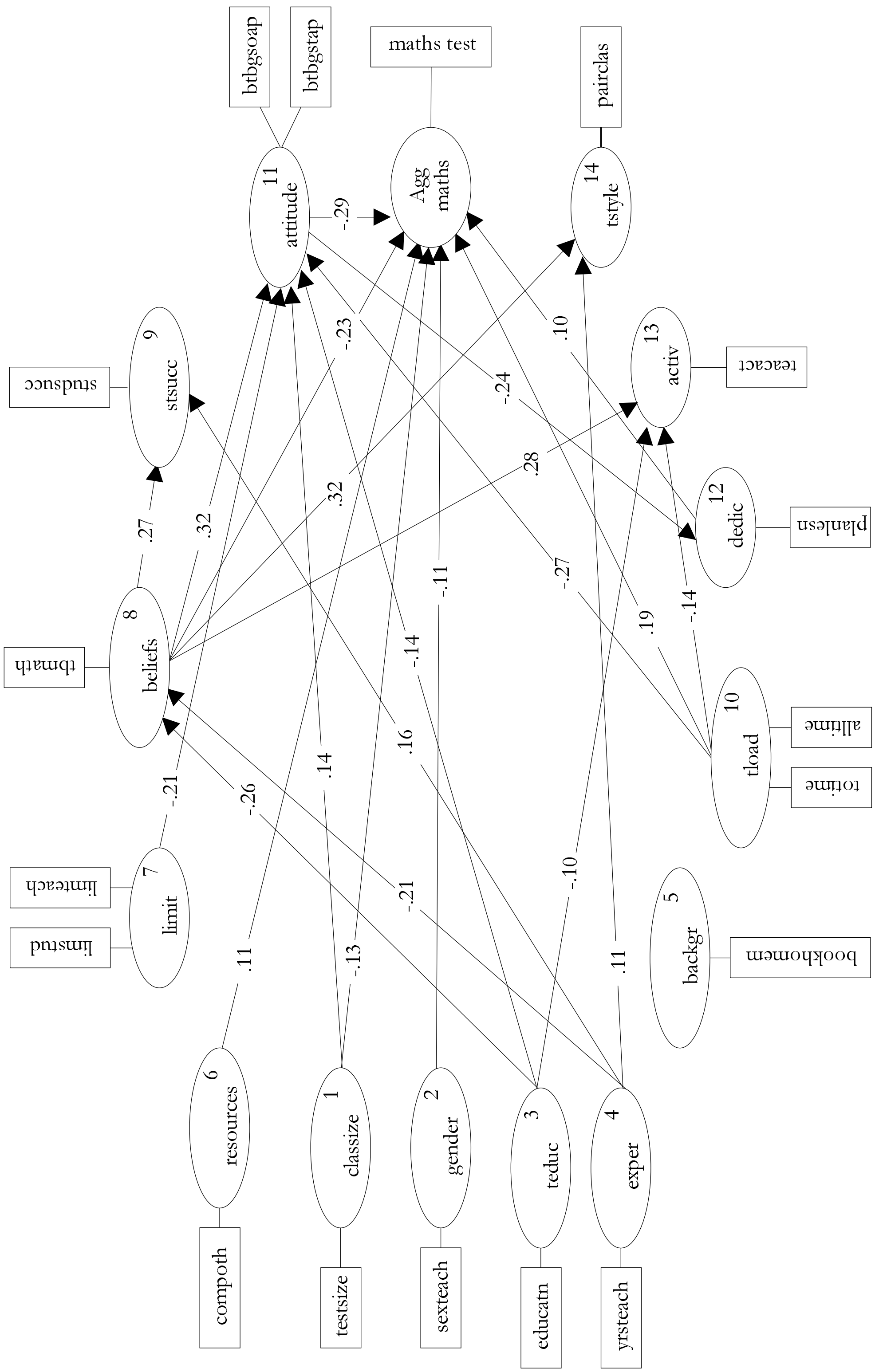

Figure 8.3
Final model of classroom-level factors only

As can be seen in the model the strongest (but negative) path to mathematics is *attitudes*. As mentioned earlier, this means that the more that teachers feel that society and their pupils appreciate their work, the lower the scores their pupils achieve in mathematics. This surprising result may possibly be attributed to the following. Teachers in general are highly regarded in rural areas and also in several urban communities around the country. However, these are also the areas where there are poor socio-economic conditions and resources and facilities are lacking. Teachers are often less qualified in these areas and therefore, although teachers may feel appreciated, their pupils may have other obstacles to contend with and therefore the scores may still be lower.

In summary, pupils of teachers that spent more time on lesson preparation (*dedic)* did not have such strong beliefs about mathematics in general, who taught smaller classes that were better resourced, were more likely to achieve higher scores in mathematics in the South African context. Interestingly no direct effect seemed to have been gauged by teachers' formal qualifications, their teaching experience, by their teaching style, or by the obstacles presented by other teachers as well as by their activities or opinions of what was needed for pupils to succeed in mathematics.

Finally, the percentage of variance explained by the model overall is 22% which is lower than that explained by the school-only model.

8.3 COMBINED SCHOOL AND CLASSROOM MODEL ANALYSIS

In this section, the process of combining the two separate models into one school-class level model is described and the results for this combined model are presented and discussed.

8.3.1 Preparation for the combined model

Once the exploration of the separate classroom and school level models was completed, an examination of the final factors that directly influenced mathematics achievement was undertaken. Only those factors that directly influenced achievement and had a path coefficient of at least .10 (absolute value) were included in the further analysis of the combined model. As it was also important to ascertain the possible interaction of the student level and school level factors, certain student level variables were aggregated to the school level for inclusion into this model, namely, students' English test score (aggeng), students' self concept in mathematics (aggselfc), students' home language (agglang) and students' socio-economic status (aggses). Once again, factors that bore a direct relationship with achievement were scrutinised as candidates for this model.

The first step was to merge the data from the mathematics teacher and principals' datasets. Schools, which did not have data for both respondents were immediately omitted from further analysis. Ultimately 183 cases were included for the combined model. Thereafter important factors from the student level data (*ses, homelang, selfconpt, mathscore*) were aggregated to provide a class score for each factor and the individual datasets created for the aggregated factors were thereafter merged with the new combined school level data. By aggregating the scores for these student level factors, it was anticipated that these would be inflated due to the aggregation bias introduced into the data. This phenomenon is well documented and discussed in the literature (see Janssen Reinen, 1996; Lietz, 1995; and Mohandas, 1999, for details). However, it was the only possibility left to explore the data prior to having to select factors for the multi-level analysis. This phenomenon is also one of the primary reasons for conducting the multi-level modelling after the exploratory stage of the analysis.

As with the other models, it was important to start the process by looking at the correlations of the factors (see Table 8.16 for those correlations with an absolute value of greater than r = 0.15) with the dependent variable, mathematics score. The same criteria were then applied as previously.

A number of high correlations were found with the mathematics score. The highest of these was between the students aggregated score for English and the students' score for mathematics where the correlation was r = .92, indicating the very strong relationship of language with mathematics. However, as mentioned earlier the correlations are clearly inflated because of the aggregation bias. The strongest correlation amongst the teacher level variables was between the teachers' perception of their worth by society and the pupils (*attitude*). However this was negative as discussed in section 8.2.6.

Table 8.16

Correlation of school and classroom background factors with mathematics score

Factor	**Latent variable**	**Pcorr Maths score (above .15)**
Students' English Test score (aggregated)	AGGENG	.92
Students' attitude (aggregated)	AGGSELFC	-.69
Students' home language (aggregated)	AGGLANG	.77
Students' SES (aggregated)	AGGSES	.77
Teacher background	TBACKGR	.38
Teachers' beliefs about maths and student success	BELIEFS	-.44
Teachers perception of their worth	ATTITUDE	-.53
Teachers activities in class	TACTIV	-.21
Teachers' workload	TLOAD	.38
Number of pupils in tested class	CLASSIZE	-.30
Number of pupils in school	SCHSIZE	.33
Geographic location of school	AREA	.42
Extent to which there is a limitation of resources in the school	RESOURCE	-.28

The factors that were included in the final combined school model can be found in Table 8.17.

Two factors were included from the previous school-level only model, six factors from the class-level only model and four aggregated student-level factors. Of these factors, only three (out of the 13) were composite variables (namely*, limits, beliefs* and *attitude*).

Table 8.17

Latent and manifest variables included in the combined school-class level PLS analysis

LATENT VARIABLES	MANIFEST VARIABLES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
MATHSCOR	Bsmmat_1			
TEACHER LEVEL FACTORS				
TLOAD	Tottime Alltime	Btbgtotl btbgalto	Time spent teaching at school Total time spent on activities related to work	No of hrs
GENDER	Sexteach	Btbgsex	Gender of teacher	1. male 2. female
RESOURCE	Compoth	Btbmmcom2	Computers used outside of classroom but still within the school	1. never or almost never 2. some lessons 3. most lessons 4. every lesson
CLASSIZE	Testsize	Btdmtoen	Number of pupils in mathematics classes that were tested	Actual number
BELIEFS	Tbmath	Btbmagr 2-4, 6-8	Teachers beliefs about maths in general	1. strongly disagree 2. disagree 3. agree 4. strongly agree
ATTITUDE	Apprec	Gensoap Genstap	Perception by teacher whether society appreciates their work Perception by teacher whether pupils appreciate their work	0. No 1. Yes
DEDIC	Planlesn	Btbgact3	Teacher preparation outside school hours – lesson planning by teacher alone	0. no time 1. <1 hr 2. 1-2 hrs 3. 3-4 hrs 4. 4hrs

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LATENT VARIABLES	MANIFEST VARIABLES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
SCHOOL LEVEL FACTORS				
LIMITS	Resourg	Genst01-05	Shortages of general facilities and learning equipment	1. none 2. a little 3. some 4. a lot
AREA	Sccomm_1	Schlcomm2	The location of the school	1. geog isolated area 2. village or rural area 3. outskirts of town or city 4. close to centre of city
STUDENT LEVEL AGGREGATED VARIABLES				
AGGENG	Totsco_1	N/a	Student mean score on English language proficiency test	Score out of 40 points
AGGLANG	Homela_1	LINGUA	Language spoken most often at home	0. other languages 1. African languages 2. Afrikaans 3. English
AGGSES	Posses_1	BSBGPS02,5-14	Computer, electricity, tap water, tv, CD player, radio, own bedroom, flush toilets, car (10 items)	0. no 1. yes
AGGSELFC	Difmat_1	N/a	Student mean score on English language proficiency test	Score out of 40 points

8.3.2 Results of the final combined school-level model

Thirteen latent variables representing 14 manifest variables were included in the analysis of the final model (see Table 8.17). Only *tload* reflected two manifest variables. The results of the outer model (see appendix 8) remained within the acceptable limits specified in Chapter 6.

During the exploration of the combined school and classroom, the dominance of the aggregated English language proficiency test was evident. Once the aggregated English score was inserted with a direct path to achievement (.88), no other class-level or school level factor had a significant path to the maths score other than the factor teachers' *beliefs* (-.11). These two variables explained 86% of the variance in the mathematics score. However, as the PLS analysis was a preparatory and exploratory method for identifying potential factors at all levels for the multi-level analysis, it was therefore decided (in the interests of identifying additional class and school level factors) to develop a final model which included the aggregated English score only with an indirect path to the maths achievement score.

Final combined school level inner model

The final inner model results are presented in Table 8.18 and are represented in Figure 8.4.

In total, 47% of the variance in the maths score was explained by eight predictors. Six of these were significant, namely, *beliefs* (p = -0.24), *attitude* (p = -0.25), *tload* (p = 0.18), *area* (p = 0.18), classize (p = -0.10) and *dedic* (p = 0.10). The factors *limits* (p = -0.09) and gender (p = -.06) were not found to be a significant predictor of mathematics achievement. The aggregated student variables were found to have strong paths to all six of the significant predictors. Therefore once the school-level and classroom-level factors were combined, pupils in smaller, more urbanised schools, who were in classes where teachers' beliefs were less strong, where teachers attitudes towards their status were more critical, where teachers had heavier teaching loads and where teachers spent more time on preparation, were those who were more likely to achieve higher results in the mathematics test. Apparently, the obstacles to the teachers' ability to teach did not produce a significant negative effect on maths achievement and neither was it significant whether pupils were taught by male or by female teachers.

Table 8.18

Inner model results of PLS on school and class-level

Factor	Beta	Correlation	Tolerance	R-squared
AGGSELFC				.49
Aggeng	-.70	-.70	.0000	
CLASSIZE				.11
Area	-15	-.28	.4006	
Agglang	-.13	-.26	4034	
Aggses	-.12	-.30	.5807	
BELIEFS				.21
Agglang	-.46	-.46	.0000	
ATTITUDE				.41
Agglang	-.56	-.63	.1760	
Tload	-.13	-.33	1232	
Classize	*.07*	*.23*	*.0682*	
TLOAD				.14
Gender	*.04*	*-.02*	*.0249*	
Aggses	.38	.38	.0249	
LIMITS				.05
Agglang	*.04*	*-.11*	*4028*	
Aggses	-.24	-.21	4028	
AGGENG				.73
Area	.19	.48	.1749	
Agglang	.66	.75	.1473	
Limits	-.16	-.27	.0458	
DEDIC				.09
Agglang	-.10	.15	5015	
Tload	.15	.21	.1461	
Attitude	-.15	-.21	.4106	
Aggselfc	-.19	-.21	.4106	
RESOURCE				.02
Agglang	*.05*	*.11*	*4028*	
Aggses	*.09*	*.12*	*.4028*	
MATHSCOR				.47
Gender	*-.06*	*-.16*	*.0352*	
Area	.18	.42	.1852	
Tload	.18	.37	.1502	
Limits	*-.09*	*-.24*	*.0925*	
Classize	-.10	-.30	.1203	
Beliefs	-.24	-.43	.1931	
Attitude	-.25	-.53	.3187	
Dedic	.10	.26	.0767	
Mean R squared				**.27**

Note: Beta coefficients in italics failed to meet the minimum criteria of .10.

The strongest predictor of achievement, *attitude* (p = -0.25) (see Table 8.18 and Figure 8.4) was explained largely by the aggregated language in the class (p = -0.56), which explained 41% of the variance in the teachers' attitude. This meant that teachers were more likely to report feeling more valued by society and their pupils in classes where most of the pupils tended to speak one of the African languages at home. Conversely, in classes where most of the pupils spoke Afrikaans or English, the teachers were more likely not to feel valued either by society or by their pupils.
Twenty-one percent of the variance of the next strongest predictor, *beliefs* (p = -.24) was also explained by the class's aggregated language spoken by the students at home (p = -0.46). Teachers tended to have strong beliefs about mathematics in classes where the majority of the pupils in that class spoke at least one of the African languages at home.

The teachers' load (*tload*) was most likely to be heavier in classes where the majority of the children were wealthier (p = 0.38). This was not predicted by gender and therefore it could not be said that female teachers tend to have a heavier load than male teachers or vice versa.

A very small proportion of the variance in the teachers reporting of obstacles (*limits*) could be explained (5%). Generally, teachers more likely to report experiencing obstacles from other teachers were in schools where the pupils were poorer and came from lower socio-economic backgrounds.

The variance in the previously dominating factor, the aggregated score of the English score, which was deliberately not modelled as a direct path to mathematics achievement, could be largely explained (73%). Three factors contributed to this, namely the location of the school (*area)* (p = 0.19), the aggregated language of the children in the class (*agglang*) (p = 0.66) and the obstacles faced by the teacher (*limits*) (p = -0.11). This meant that classes where children tended to speak more English at home, who were based in a more urban environment and where teachers tended not to report too many obstacles from their fellow teachers, were those most likely to have the higher scores in English.

Teachers that spent more time preparing their lessons (*dedic*) tended to be those who taught pupils who had a stronger self-concept in mathematics, but who did not feel appreciated by society or their pupils; who taught classes where there were more English-speaking or Afrikaans-speaking pupils and were those who were more likely to have a heavier workload.

The location of the school (p = -0.15), as well as the pupils' socio-economic status (*ses)* (p = -0.20) were both found to be predictors of the size of the class that was tested. Schools in urban areas tended to have smaller classes and larger classes were found to be associated with pupils from poorer *SES* backgrounds. Larger classes were found to contain predominantly African-language pupils.

In Figure 8.4, the factors *resource* and *gender* are not depicted as only significant direct paths are presented in the figure.

A closer look at the factors that had an indirect effect on maths achievement (see Table 8.19) reveals that in addition to the six predictors that had a significant direct effect on achievement, another two factors (*agglang* and *aggses*) had significant indirect effects on achievement. Of these, the strongest was the language that pupils spoke at home (*agglang*, p = 0.27). Those in classes where most pupils spoke English or Afrikaans at home were more likely to have higher mathematics scores.

Agglang also had an indirect effect on *dedic* meaning that indirectly pupils from homes where English or Afrikaans is almost always spoken have a positive effect (p = .17) on the amount of lesson planning that the teacher does after hours.

Pupils, who had a weaker self-concept about mathematics, were more likely to come from schools in more rural areas (p = -.13) and to be those who tended to speak an African language at home (p = -.46).

Finally, the factors in this combined model explained 27% of the variance in the model, which may be considered a medium strength model. However, the variance explained is far less than that in the strong school-level (41%) only model, but more than the weaker strength classroom-only model (22%). This suggests the strength of the classroom-level factors as well as the additional student-level factors that were included, is greater than those at classroom-only level.

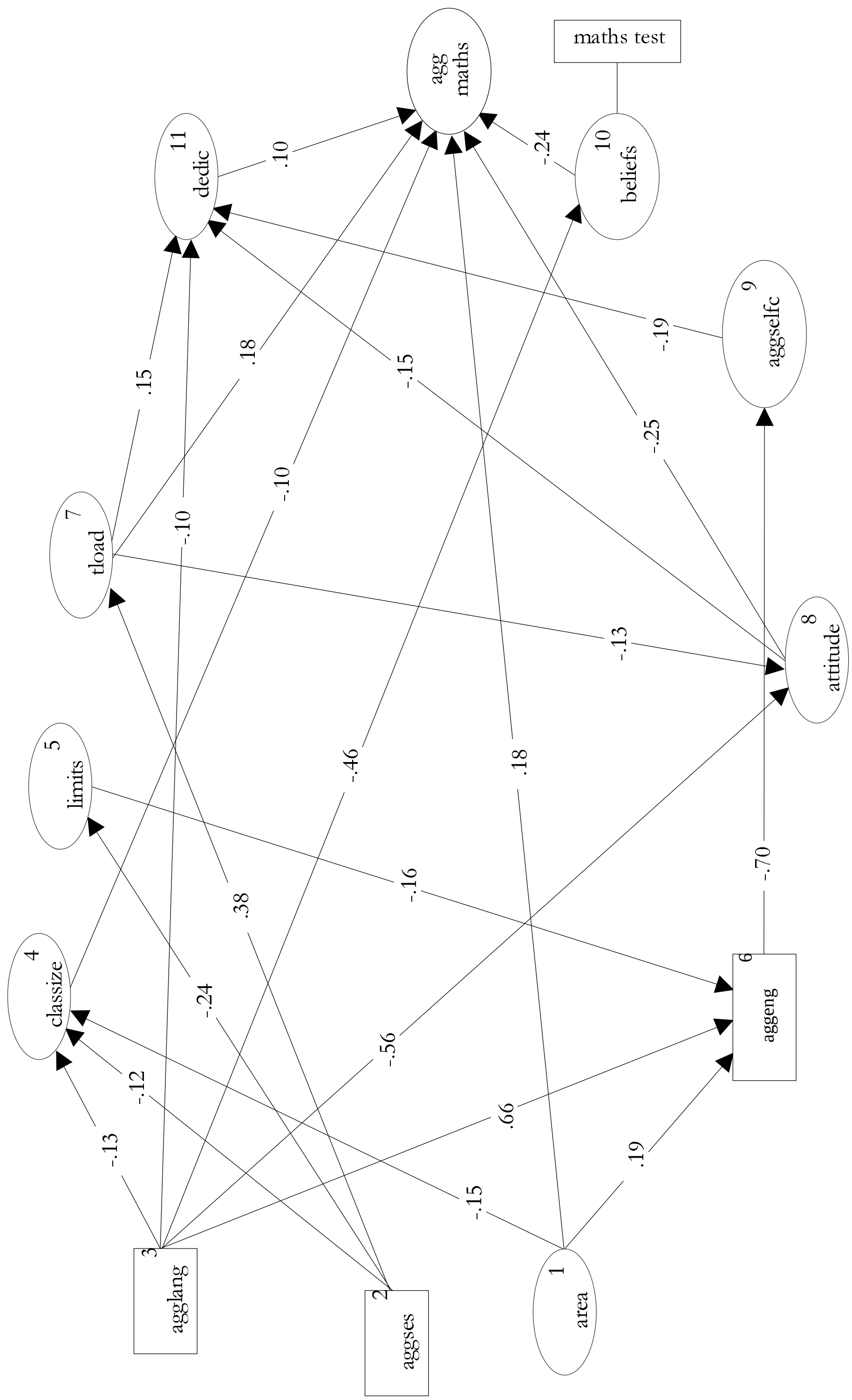


Figure 8.4
Final combined PLS school level model

Table 8.19
Inner model effects (direct, indirect and total) for school-class level factors influencing students' achievement in mathematics

Factor	Direct	Indirect	Total	R-squared
AGGSELFC				**.49**
Area	-	-.13	-.13	
Agglang	-	-.46	-.46	
Aggses	-.58	-	-.58	
Limits	-	.11	.11	
Aggeng	-.70	-	-.70	
CLASSIZE				**.11**
Area	-.15	-	-.15	
Agglang	-.13	-	-.13	
Aggses	-.12	-	-.12	
BELIEFS				**.21**
Agglang	-.46	-	-.46	
ATTITUDE				**.41**
Gender	-	-.01	-.01	
Area	-	-.01	-.01	
Agglang	-.56	-.01	-.57	
Aggses	-	-.06	-.06	
Tload	-.13	-	.13	
Classize	.07	-	.07	
TLOAD				**.14**
Gender	*.04*	-	.04	
Aggses	.38	-	.38	
LIMITS				**.04**
Agglang	*.04*	*.04*		
Aggses	-.24	-	-.24	
AGGENG				**.63**
Area	.19	-	.19	
Agglang	.66	-.01	.65	
Aggses	-	.04	.04	
Limits	-.15	-	-.15	
DEDIC				**.09**
Gender	-	.01	.01	
Area	-	.03	.03	
Agglang	-.10	.17	.07	
Aggses	-	.07	.07	
Tload	.15	.02	.17	
Limits	-	-.02	-.02	
classize	-	-.01	-.01	
Attitude	-.15	-	-.15	
Aggeng	-	.13	.13	
Aggselfc	-.19	-	-.19	

Table continued on next page

Factor	Direct	Indirect	Total	R-squared
RESOURCE				**.02**
Agglang	.05	-	.05	
Aggses	.09	-	.09	
MATHSCOR				**.47**
Gender	-.06	.01	-.05	
Area	.18	.02	.20	
Agglang	-	.27	.27	
Aggses	-	.12	.12	
Tload	.18	.05	.23	
Limits	*-.09*	.00	-.09	
Classize	-.10	-.02	-.12	
Beliefs	-.24	-	-.24	
Attitude	-.25	-.01	-.26	
Aggeng	-	.01	.01	
Aggselfc	-	-.02	-.02	
Dedic	.10	-	.10	
Mean R squared				.27

*Notes: * figure rounded off to 2 decimal points; ** total effect smaller than direct and indirect paths together because of rounding off.*

8.4 CONCLUSION

When South Africa participated in TIMSS in 1995, only student–level could be analysed and therefore the 1999 data presents a unique opportunity to explore the factors not only at student level, but also at classroom and school level that may have effects on achievement in mathematics. In this section the results of the different models will be summarised and related to the conceptual model of the study as introduced in Chapter 5.

8.4.1 Conclusions at Student level

Data pertaining to the students' home background, their personal characteristics, their aptitude and competencies were explored. A high percentage of variance (50%) in the pupils' mathematics score was explained. The six factors found to have a direct effect on mathematics, namely the pupils' proficiency in English, their own self concept in terms of mathematics, the language pupils spoke at home, their socio-economic status at home, and whether or not they, their friends and their mother thought that maths was important and language of learning in the classroom. All of these factors were found to have a significant direct effect on the South African pupils' performance in mathematics. When taking into account those factors on student level, one can conclude that pupils tended to achieve higher scores in mathematics when their language proficiency in English was higher, spoke English or Afrikaans at home, came from wealthier families, were based in classes where the language of learning was mostly the previously official languages of instruction and who thought mathematics was important (as did their friends and mothers). This confirms the impressions and experiences of many people in the South African context for the first time on a significant scale.

8.4.2 Results from the school-only level

Some important aspects of school quality related to school leadership, parent involvement, school profile, physical resources, human resources, autonomy, learning environment and school administration were explored in the data from the school principal's questionnaire. Additionally, two important antecedents related to the type of community and the home language of the student were included in the model. Ultimately (as can be seen in 8.1.3, Table 8.5) 62% of the variance in the students' scores in mathematics could be explained by three factors at the school level, namely, the community where the school was located, the influence that the teachers union have on the curriculum and an aggregated student variable, namely the extent to which the pupils in the class spoke the language of instruction as their first language.

A very strong effect was seen of the pupils' home language on their performance in mathematics. Clearly a key problem is that in most of the schools the language of instruction and the mother tongue of the teachers and/or the students are different. The result of this is that students' achievement in mathematics (and possibly other subjects) is negatively affected, as can be seen from these results of language and mathematics achievements (see 8.2.3; Table 8.9).

The influence of the location of the school in rural or urban areas on mathematics achievement is not surprising given the under-development in rural areas in South Africa. However, as 50% of South Africa's population live in rural areas, the fact that students attending school in rural areas perform worse in mathematics than those attending schools in urban areas should be of serious concern to the education and other authorities and policy-makers. Although these last two factors are largely beyond the control of the school (namely the location of the school and the home language of students) they need to be considered by education planners and policy makers. Furthermore, identifying these factors helps to explain the overall results and to alert those in authority as to the effect of these variables on students' achievement in mathematics.

A third factor identified at school level as influencing achievement was that of the extent of the teacher union's influence on the curriculum, which was negatively related to achievement. Although the data suggest this relationship, caution needs to be taken with regard to the interpretation of this outcome. This is primarily due to the conclusion being drawn based on a single item in only the school questionnaire with little further interpretation possible from the original question asked.

8.4.3 Results on classroom level

From the mathematics teacher questionnaire, a number of classroom level factors were also explored and these resulted in including the following factors in the model: teachers' gender, teaching experience, teachers' level of education, time spent on activities, lesson preparation, teaching load, time on task, teachers' attitudes, success attribution, teachers' beliefs, teaching style, resources, limitations, and class size. In total, this model (see 8.2.6; Table 8.14) explained 46% of the variance in the pupils' mathematics scores by seven factors - the teachers attitudes, their beliefs about mathematics, the extent of their teaching and other workload, the size of the class they are teaching, their gender, resources and their dedication towards lesson preparation.

An interesting outcome was the strength of teachers' attitudes, beliefs and dedication as predictors of pupils' achievement. Teachers' commitment appears to play a key role in pupils' performance. This finding is significant against the background of the situation in many South African schools, particularly in those where there are African pupils taught by African teachers. In these schools the conditions are the worst: limited resources and facilities, large percentages of under-qualified teachers, pupils from poor socio-economic backgrounds and instruction in a secondary language. Therefore, it comes as no surprise that many teachers are also demoralised. However, these results show that those who manage to remain committed to their profession and practice may make a significant difference in their pupils' performance. The relatively low contribution of class sizes as a predictor of achievement confirms previous findings noted in Cohn and Ressmiller (1987). In the case of South Africa, those classes with large numbers of pupils (on average 50 pupils) are also those at schools with poor conditions described earlier and therefore it is possible that a type of bottom effect is felt here and therefore, the effect of the actual number of pupils is slight.

At this stage the fact that a larger variance on school level (62%) is explained by school level factors compared to that explained by classroom-level factors (44%) may almost certainly be attributed to the presence of the first language speakers in the school-level model and its absence on classroom level.

8.4.4 Results of the combined school-class level model

The school level model and the class-level model were combined meaning that the predictors of mathematics achievement were selected from both models and combined with four aggregated student level factors into one model. Therefore factors related to teachers' characteristics, pupils' home background, their aptitude, their attitudes, school quality, teaching requirements, curriculum quality and instructional quality were all explored in one model. Finally, six factors were found that had strong effects on pupils' achievement in mathematics and that explained 27% of the mathematics score. These were the location of the school, class size, the attitude of the teacher, teachers' beliefs about mathematics, the teachers' workload (including teaching) and their dedication toward lesson preparation.

8.4.5 Concluding remarks

Throughout the exploratory phase of the PLS analysis the strength of the effects of the language variables were in evidence and as in the case of the school level and combined school level models the dominance was overwhelming. From the PLS results, it is clear that the better pupils perform on the English language test the better they perform on the mathematics test. A similar significant result was found on school-level where the mathematics results were better where there were a larger number of first language speakers (both English and Afrikaans) in the class. Strong relationships were also found between English proficiency scores and other variables such as the home language and SES.

Before proceeding onto the next phase of analysis, the multi-level analysis, it is worthwhile to reflect upon what the exploratory analysis reveals in relation to the conceptual model proposed for the study in chapter 5 and presented for convenience in Figure 8.5. The 17 factors found at the student, classroom, school and combined school-classroom level that have a direct effect on mathematics achievement appear to be spread across the conceptual model.

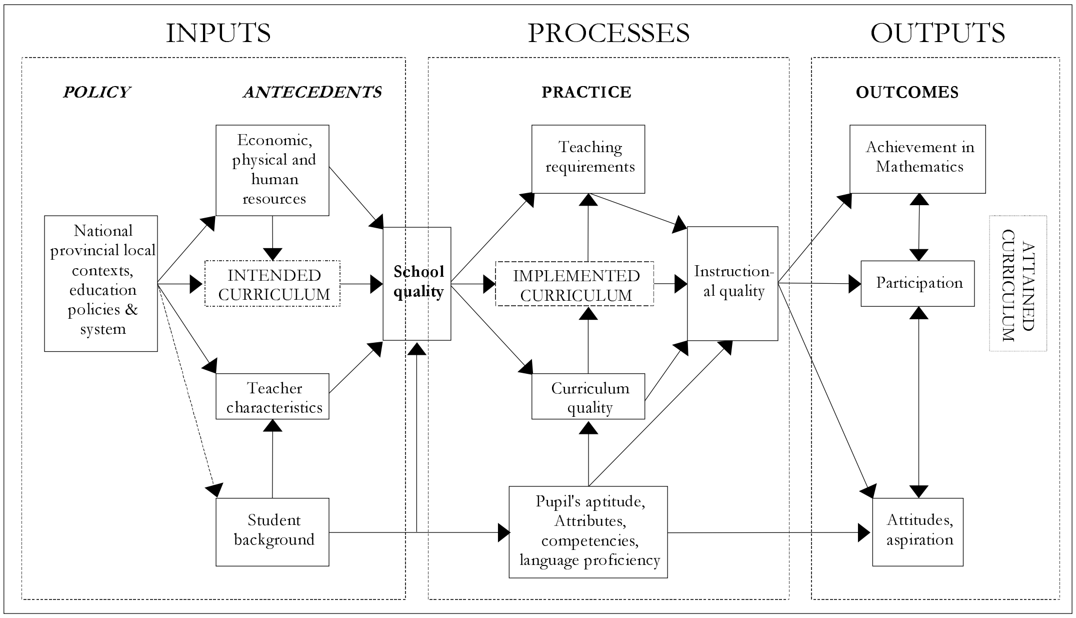


Figure 8.5
Outcome of exploratory analysis in relation to the Conceptual Frame work for the study

Starting from the **inputs** into the education system, the location of the school which lies within the component "*national, provincial, local contexts…..*" was found to have a direct influence on achievement with pupils from urban areas achieving higher scores. No factors were found under the "*economic, physical and human resources* that were significant. However, under *teacher characteristics*, three factors were found. The gender of the teacher, the attitudes of the teacher and the teachers' beliefs had a direct effect on achievement. Male teachers tended to produce the higher results whilst teachers with strong mathematical pedagogical beliefs and those feeling appreciated by society and their pupils were more likely to produce lower results. Interestingly however, once the combined model was developed, gender no longer had a direct effect on achievement. A number of factors were also found amongst the *pupils' home background* that had a direct effect on achievement, namely home language, SES and attitudes about the importance of mathematics. Children from homes where African languages were used were more likely to achieve lower scores than those from homes where English or Afrikaans was spoken. Those from poor homes were also less likely to achieve high scores in mathematics. Better performance in mathematics tended to be found amongst children who came from homes where the mother believed that mathematics was important and where the child and their friends concurred with this.

An analysis of the factors found amongst **processes** in the model revealed a number of these had a direct effect on achievement. Three factors were found under the category of *school quality*, namely computers in the school, the number of children that spoke the official medium of instruction regarded therefore as first language speakers and the teachers' unions influence on the curriculum within the school. Pupils in schools where computers were used for teaching and learning, where there were more first language speakers and where the teacher unions had little influence on the curriculum tended to achieve the higher scores in mathematics. However, once the combined model (school-classroom) was developed, the computers no longer had an effect on achievement. Under *teaching requirements*, two factors were identified as having a direct effect on achievement. Pupils in classes where teachers spent more time on teaching and more time with work related activities at school tended to achieve higher results in maths. Pupils in smaller classes were also more likely to achieve better results, although in the combined model, this factor no longer had an effect on achievement. Only one factor could be identified under *curriculum quality*, as unfortunately key variables such as the content coverage could not be analysed. However, the amount of time spent by the teacher preparing the lessons was found to have a positive effect on their pupils' achievement. Under *pupil's aptitude, attributes and competencies*, one very important factor was identified. The English language proficiency of a pupil was found to be strongly related to their mathematics achievement. Pupils who had high scores on the English test were more likely to achieve high results on the mathematics test than those who did not.
There were two factors in the category of *instructional quality* that had direct effects on achievement. At first pupils in classes where teachers frequently organised and allowed their pupils to work in pairs or small groups either with or without the assistance of the teacher tended to achieve higher scores in mathematics. However in the combined model, this factor lost its effect on achievement. Pupils in classes where the pupils and the teachers mostly interacted in the official media of instruction (English or Afrikaans) were more likely to achieve better results in mathematics.

Finally, regarding the **outputs** of the education only one factor was found under the category of *attitudes and aspirations*. Pupils who had a strong self-concept in mathematics and did not find it particularly difficult, did not believe that they were not talented in maths, or that maths is more difficult for them than for their classmates and believe that maths is one of their strengths were much more likely to achieve higher scores in maths. Although various variables were analysed regarding *participation*, no effect was found on achievement. Although younger pupils and those with higher aspirations were more likely to participate in school, no relationship was found at the student-level between pupils' attendance and their achievement in mathematics.

In conclusion, this exploratory phase using PLS was very important given the large numbers of variables available at each level in the analysis. However, as PLS is uni-level modelling technique and the concerns about the aggregation bias that results from aggregating scores on student level to school level where some of the effects might be inflated meant that the analysis could not be concluded at this stage of the research. It is for these reasons that it was desirable to continue the analysis of this data using multi-level modelling with these variables listed above for the final outcomes of this research and therefore the analysis is continued in Chapter 9 with the application of the Multi-level analysis (MLn).

CHAPTER 9
Results of the multi-level analysis

Multilevel analysis was applied in order to take into consideration the structure of the data. In total, 15 variables were included into the models, six on student-level and nine on school-level. In a two-level model, the Null model revealed that 55% of the variance in the mathematics score lay at the school level with the remaining 45% being found at student-level. The Student-model incorporated six variables, which explained 62% of the variance at school level and 41% at student level. The Student-school model explained 78% of the variance between schools and 50% within schools. Ultimately of the 15 variables predicted to influence achievement, 11 were significant. The pupils' performance on the English test proved to be the factor that explained the greatest proportion of variance both between schools and within-schools.

Whilst in Chapter 8 relationships were found in PLS, it is important to reveal whether these would 'survive' in a multi-level analysis and, if not, how these relationships may change once inserted into a multilevel model. In this chapter, the results of the multi-level analysis applying MLnWin are described and discussed. In Chapter 6 (6.4) the theoretical background, technical specifications and the methods were described and reference is made to these in this chapter. The structure of the chapter is as follows. Firstly the selection of the variables included in the MLN analysis and a description of the initial model is given and the preparation of the data is elaborated in 9.1. The specifications of the models and the results of the analysis are described and discussed in 9.2. These results are summarised and discussed in 9.3.

9.1 THE INITIAL MULTI-LEVEL MODEL

Before describing the initial multi-level model, first the selection of the factors or variables that are included in the analysis will be briefly described. In Chapter 8, the variables that were found to have a significant effect on mathematics achievement in

the PLS analysis were summarised (8.4). These are given in the form of the PLS variable labels and the corresponding labels that were allocated to the same variables included in the multi-level analysis (see Table 9.1). As was mentioned in chapter 8, the PLS analysis provided a useful precursor to the multilevel analysis in identifying which variables to include in the multi-level analysis. Finally, six variables on student level (all of which had a direct effect on achievement using PLS), two variables on school level (of which both had a significant effect in the school-only analysis but the school enrolment (*enrolmt)* did not in the combined model) and seven variables on class level were included (of which six were significant in PLS) (see Table 9.1). The reason for including an additional variable that did not have a significant effect, namely, the number of pupils enrolled in the school (*enrolmt*) was due to the important policy implications of this variable, especially in South Africa.
The student-level and school-level variables that ultimately are included in the multi-level analysis are depicted in Table 9.1.

Table 9.1
Names of variables included in MLN and their equivalent labels in PLS

Latent variable PLS	**Variable in MLN**	**Description of variables**	**Range***
Student level			
homelang	hlang	language pupils spoke at home	0-3
ses	ses	socio-economic status	0-10
engtest	engtest	pupils' English test score (re-scaled in analysis from (0-40)	–17-23
difmath	selfconp	pupils' own self concept in terms of mathematics	0-15
mathimpt	impmath	whether or not they, their friends and their mothers thought that maths was important	0-9
ra_lang1	radiolg	language on the radio they most often listen to	0-2
School level			
classize	clsize	size of the class the teachers were teaching	0-131
area	location	community where the school was situated	0-3
lanlearn	claslang	language spoken most often in the class by pupils and teachers	0-5
beliefs	mathphil	teachers' beliefs about mathematics	0-14
attitude	status	attitude of the teacher towards the profession	0-2
dedic	planning	teachers' dedication toward lesson preparation	0-4
school	enrolmt	number of pupils enrolled in a school	0-1913
tload	teachtim	teachers' teaching load	0-64
	worktim	teachers' total workload	0-78

Note: * All the scores were rescaled for the MLwiN analysis.

The initial model

The TIMSS-R data were collected on student-level, classroom-level and school-level. However, achievement and background data were collected only from one class per school and therefore no between-class within-school variations can be observed. This resulted in two levels of data being available, the student-level and the combined classroom-school-level (from now on referred to only as the school-level) and therefore a 2-level model (see Figure 9.1) was proposed.

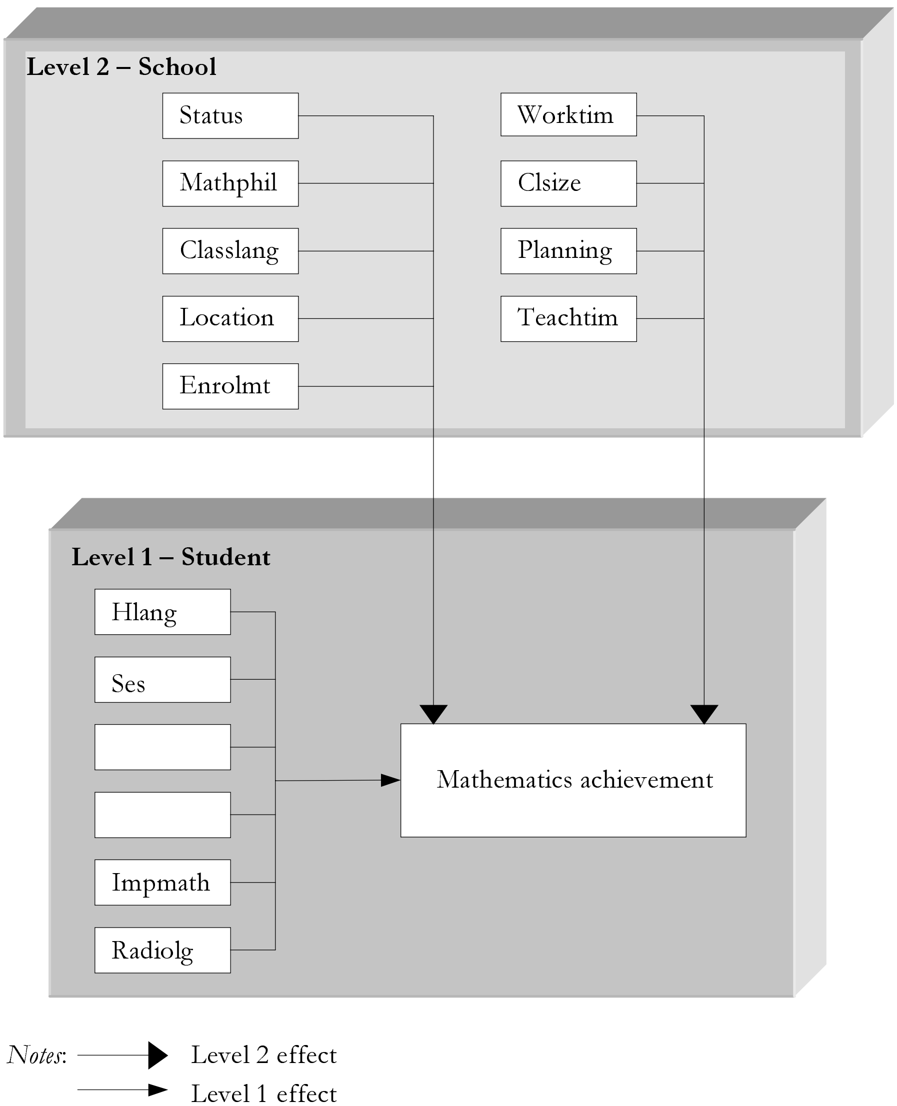


Figure 9.1
Initial 2-level proposed model for multi-level analysis

The relationship between the independent variables on school-level and student-level on the dependent variable mathematics achievement was investigated. Based on the results of the PLS analysis, it was hypothesised that nine independent variables on school level and six independent variables on student level would directly influence pupils' achievement in mathematics.

It is suggested that all the predictors in the model influence achievement directly as none of these can be examined indirectly in this model, unlike the PLS analysis.

Preparation of the data

In order to test the above model (Figure 9.1), an extensive process of data preparation had to take place. Firstly a dataset had to be prepared containing no missing values (see Chapter 6) and all the student and school level variables to be analysed were merged into one dataset. As the analyses were done using weighted data, the data were weighted using the information from South Africa's sampling frame. The identifiers that are used in the analysis are school and student and therefore the data set was sorted according towards these variables. For the sake of interpretation some variables were rescaled where the lowest meaningful value was set to zero. More information on the procedures and the rationale for the procedures is provided in section 6.4.3. Ultimately, 183 schools and 7 651 South African pupils were included in the analyses.

9.2 RESULTS OF THE MULTI-LEVEL ANALYSIS

The results of the multi-level analysis are presented and discussed in this section. First, the null model is given, followed by the student-model and the student-school model. Thereafter the proportion of variance is described and discussed. Finally the extension of the student-school model with the random slopes of the average English test scores is given. All the models that were analysed may be found in Appendix 9.1, while the results mainly discussed here are summarised in Tables 9.2 and 9.3.

The Null Model

A *null model* (or unconditional model) containing only the dependent variable (the mathematics score) was run to estimate the total variance in the mathematics score and to obtain the estimates of the amount of variance available to be explained at school-level and at student-level discussed in Chapter 6. The null model does not include any student-level or school-level variables.

The *null model* specified in the first step of running the two-level model is:

$$MATHTEST_{ij} = \beta_0 + u_{0j} + e_{0ij} \quad (1)$$

where

$MATHTEST_{ij}$ is the specific score on the Mathtest of the i^{th} student of the j^{th} school, written as the sum of:

β_0: the intercept (the grand mean of the mathematics scores)

u_{0j}: the average score of the j^{th} school

e_{0ij}: a residual part, the student error term.

The average school score (u_{0j}) and the residual part (e_{0ij}) are assumed to have a normal distribution with a mean zero.

As shown in Table 9.2 the intercept β_0 of the Null-Model is: 288.0, resembling the grand mean of the mathematics scores. (The grand mean differs slightly from the South African mean score of 275 on the international test due to the fact that a number of schools could not be included in the MLn-analyses).

Table 9.2 also shows that in the Null-model the between-school variance is 6 520 and the variance on student level (within-school-variance) is 5 342. More than half of the variance is on school level (55%) whilst 45% of the variance can be situated on student level. This means that the mathematics score of a pupil is linked to the school that the pupil attends, by more than 50%.

Table 9.2

Table Multi Level analysis of the South African TIMSS data with the Math-test score as dependent variable (weighted data)

Fixed effect	**Null Model (Model 0)**	**Student Model (Model 6)**	**Student-School (Model 15)**
student level			
Intercept	**288**	**278**	**299.5**
hlang		5.35 **	3.27
ses		1.20 **	.88*
engtest		4.07 **	4.00**
selfconp		-6.32 **	-6.29**
impmath		6.39 **	6.35**
radiolg		4.75 **	3.95**
school level			
status			-17.27**
mathphil			-4.46**
location			8.00**
claslang			2.59**
enrolmt			.00
worktim			.52**
clsize			-.27
planning			8.02*
teachtim			.10
Random effects			
School	6 520 (55%)	2 451	1 336
Student	5 342 (45%)	4 570	4 560
Difference in deviance	N/A	1 340#	132.80#

Notes: N = 7 651 pupils in 183 schools (one class per school);
* t-value > 1,96, this resembles a confidence interval of 95%;
** t-value > 2,58, this resembles a confidence interval of 99%;
# The difference between the deviances is significant (p<.001).

Table 9.3

Explained proportion of variance

	Model		
	0	**6**	**15**
School level Variance	6 520 (55%)	2 451	1 336
Explained proportion of variance			
When compared with model 0	NA	.61	.78
Due to the last added variables	NA	NA	.17
Student level Variance	5 342 (45%)	4 570	4 560
Explained proportion of variance			
When compared with model 0	NA	.41	.50
Due to the last added variables	NA	NA	.09

Note: The harmonic mean = 36.71; NA means not applicable.

Student-model

Once the null model was ascertained, the next step was to investigate how much of the variance the student-level variables explain before entering the school-level variables and the student-level variables into the same model. To calculate the effect of the student variables, they were inserted one by one into the model according to the step-by-step procedure outlined in Chapter 6.

The student-model can be written as:

$$\text{MATHTEST}_{ij} = [\text{null-model}] + [\text{student-component}]$$

with

$$[\text{null-model}]: \beta_{0ij} = \beta_0 + u_{0j} + e_{0ij} \qquad (1)$$

and

$$[\text{student-component}]: \beta_1\text{HLANG}_{ij} + \beta_2\text{SES}_{ij} + \beta_3\text{AVER\_ENG}_{ij} + \beta_4\text{SELFCONP}_{ij} + \beta_5\text{IMPMATH}_{ij} + \beta_6\text{RADIOLG}_{ij} \qquad (2)$$

The results of the student model are summarized in Tables 9.2 and 9.3 with Model 6 being the model in which all six student-level factors (hlang, ses, engtest, selfconp, impmaths and radiolg) have been inserted. Table 9.2 shows that in the student model (Model 6), all six student-level factors are highly significant implying that all factors do have an influence on mathematics achievement. It presents the effects of the different variables. Combined with the range of the variables (as seen in Table 9.1), the effect of for example SES (range 0-10) on mathematics achievement can be large as 12 scale points on the test (SES score 0 as opposed to SES score 10 x 1.2).

The results in the table mean that a pupil that has a score 0 on all the student variables is predicted to have a score of 278 on the mathematics test. The predictive value of the model is best illustrated by means of a couple of examples. In the model, for SES if Pupil A comes from a low socio-economic background (for example with only one item listed) (score = 1 x 1.2) and Pupil B from a high SES background (scale score = 10 x 1.2), then Pupil B is predicted to score an additional 10.8 scale points on the mathematics achievement test due to the SES difference between the two.

A closer look at the language variables, is revealing if one takes two pupils with different characteristics, Pupil A who achieves a mean score of 10 points (rescaled = -7 points) on the English test and Pupil B who scores 24 points (rescaled = +7), (the average achieved by native English speakers see Chapter 7). The difference predicted by the model on the mathematics test is therefore 57 points (-28.5 pts for pupil A and +28.5pts for pupil B). Furthermore, the model predicts that if Pupil A speaks an African language at home (hlang = 0) and never listens to an English radio station (radiolg = 0) and if Pupil B speaks English at home (hlang = 3 x 5.35 = 16.05) and always listens to an English radio station (radiolg = 2 x 4.75 = 9.5) then Pupil B will score an additional 25.55 points more than Pupil A based only on these language variables and a total of 54.05 on the three variables and a difference of 82.55 points. This is a substantial number of points given that the average score was 275 for the whole population of South African pupils (8 146).

In sum, the higher a student scores on the variables hlang, ses, engtest, impmaths, radiolg, and selfconcept (the latter having a negative scale) the better the mathematics achievement tends to be. The data show (see Appendix 9.1) that the most significant contributor to the variance explained both between schools and within-schools, is the pupils' performance on the English test.

As can be seen in Table 9.3, the student-model (Model 6) explains 62% of the total variance at school level (i.e. 61% of the school level variance in the null-model). On the other hand, the student model explains 41% of the variance at student level. The explained variance at student level in Model 6 is not 41% of the student level component of the variance in the null-model. The reason for this lies in the fact that the variance between students is not exclusively situated at student level, but also at school level (or in other words: variance between schools is variance between the students of these schools). This effect is accounted for (in MLnWin) when the explained proportion of variance on student level is being calculated.

Finally, Table 9.2 shows that the difference between the deviances of the student-model (Model 6) and the null-model are highly significant. The deviation is a measure for the likelihood of the appropriateness of Model 6 as compared to the null-model. The data show that indeed the Model 6, the student-model, is a highly significant improvement as compared to the null-model.

Student-School-model

After the insertion of the student-level variables, the school-level variables (see Table 9.1) were included step-by-step in addition to the student-level variables resulting in the student-school-model, or the full model (Model 15).

The full model can be written as:

$MATHTEST_{ij}$ = [null-model] + [student-component] + [school-component]
with
[null-model]: $\beta_{0ij} = \beta_0 + u_{0j} + e_{0ij}$ (1)
and
[student-component]: $\beta_1 HLANG_{ij} + \beta_2 SES_{ij} + \beta_3 AVER\_ENG_{ij} + \beta_4 SELFCONP_{ij} + \beta_5 IMPMATH_{ij} + \beta_6 RADIOLG_{ij}$ (2)
and
[school-component]: $\beta_7 STATUS_{ij} + \beta_8 MATHPHIL_{ij} + \beta_9 LOCATION_{ij} + \beta_{10} CLASLANG_{ij} + \beta_{11} ENROLMT_{ij} + \beta_{12} WORKTIM_{ij} + \beta_{13} CLIZE_{ij} + \beta_{14} PLANNING_{ij} + \beta_{15} TEACHTIM_{ij0}$ (3)

The results of all the intermediate models (Models 7 – 14) can be found in Appendix 9.1, while Tables 9.2 and 9.3 present the results of the full model (Model 15) that includes all the student and school level variables from Table 9.1.

When school variables are added to the model, home language (hlang) is no longer significant (this is already the case when the first school-variable is added; see Model 7, Appendix 9.1), whilst socio-economic status become less significant. Of the nine school-level variables in the full model, six are significant (of which five highly significant). However, the size of the school, the size of the class, and the amount of time teachers spend teaching are not significant, which could be an effect of the other variables in the model.

A closer look at the language variables reveals the following effects: if Pupil A speaks an African language at home (hlang = 0) and Pupil B speaks English at home (hlang = 3) then the student-school model predicts that Pupil B will achieve 9.87 points more on the mathematics test than Pupil A meaning that whilst Pupil A scores 299.5 on the mathematics test, Pupil B scores 309 points (controlling for the other variables in the model). Adding the other student-level language variables indicate that Pupil A, who scores 10 points on the English language test and never listens to an English radio station would achieve a score of 271.5 (299.5-28 + 0) versus Pupil B who scores 24 points on the English test and always listens to an

English radio station, a mean score of 345.27 points for the mathematics test (299.5+9.87+28+7.9) resulting in a difference of 73.5 points between the two students (again, controlling for the other variables in the model). However, if the school-level language variable is also added, then the model predicts that if Pupil A is in a classroom where the language of the test is rarely used as a language of learning, then they will achieve no additional points, but Pupil B who is in a classroom where this is the case will achieve an additional 13 points on the mathematics test. This means that Pupil A is predicted to achieve only 271.5 points compared to pupil B who is predicted to achieve finally 358.22 points on the test taking into account only the language variables in the model.

Additional observations of the effects in the model are that pupils in classes whose teachers reported the strongest pedagogical beliefs about mathematics (mathphil = 14) are predicted to achieve about 62 points less on the mathematics test compared to pupils whose teachers did not. Secondly, that teachers' dedication makes a substantial difference to pupils' performance. Pupils whose teachers spend the most time working (worktim = 78) at school compared to others may achieve as much as 40 points more on the mathematics test. Furthermore, pupils of teachers that reported spending a lot of time planning lessons in their own time (planning = 4) may achieve up to 32 points more on the mathematics compared to others whose teachers spend no time. On a different note, pupils who are in isolated rural schools (location = 0) are predicted to achieve 24 points less than pupils who attend schools in city centres (location = 3). Pupils in the largest class in the sample are predicted to achieve up to 35 points less than pupils in smaller classes.

In the final model (see Model 15) much of the variance in the score is explained between schools (78%) and only 22% of the variance could not be explained by the variables in the model. The decrease of the variance on student-level in the full model in combination with the decrease of school-level variance resulted in the fact that 50% of the variance between students (within-schools variance) could be explained. The difference between the deviances of the full model (Model 15) and the student model (Model 6) is highly significant, meaning that the full model is again a significant improvement when compared to the student model. One may conclude that the full model is the model that fits the data the best.

What is interesting to observe is that once the school level variables are introduced, the effect of home language (hlang), which was significant in the student model lost its significance. This was a direct consequence of the introduction of *status* (being 'teacher's attitude to the profession') in the model (see model 7 in Appendix 9.1). The fact that the effect of (home language (hlang) and (to a smaller extent of) SES disappear when school variables are added to the model means that these variables are strongly related to school variables such as attitude of teachers towards the profession (status), teachers' beliefs about mathematics (mathphil), the community where the school is situated (location), language most often spoken in the class (claslang), teachers' total workload (worktim) and teachers' dedication toward lesson preparation (planning).

Proportion of variance explained by the consecutive models

In each of the models, the *variance components* explain the total amount of variance that has to be explained as well as the total variance that is explained at each level (i.e.: at student or at school level; see Appendix 9.2).

In the final model (Model 15; Table 9.3), a higher proportion of variance is explained between schools (78%) than within-schools (50%). Of the 55% of the total variance to be explained at school level, a relatively large percentage (41%) is explained in the student model between schools, by the pupils' performance on the English test (engtest) (see model 3 in appendix 9.2). The same variable also contributes 27% to explaining the student-level variance of 45%. This is in contrast to a variable such as the importance of mathematics (impmath; see model 5 in appendix 9.2) which in itself only contributes an additional 1% of the between-school variance and 5% to within-school variance.

As seen in Table 9.3, the student model explains 62% of the between school variance, whilst only 41% of the within-school variance (student level) is explained. The full student-school-model explains a further 17% of the variance between schools (62% to 79%) and only a further 9% of the variance within-schools (41% to 50%). The largest contributing variable at school- level is status (10% on school-level and 5% on student-level) (see model 7 in appendix 9.2) and enrolment, lesson planning and teaching time contributed nothing in terms of explaining the variance either between or within-schools. Class size did not contribute to explaining the variance within-schools.

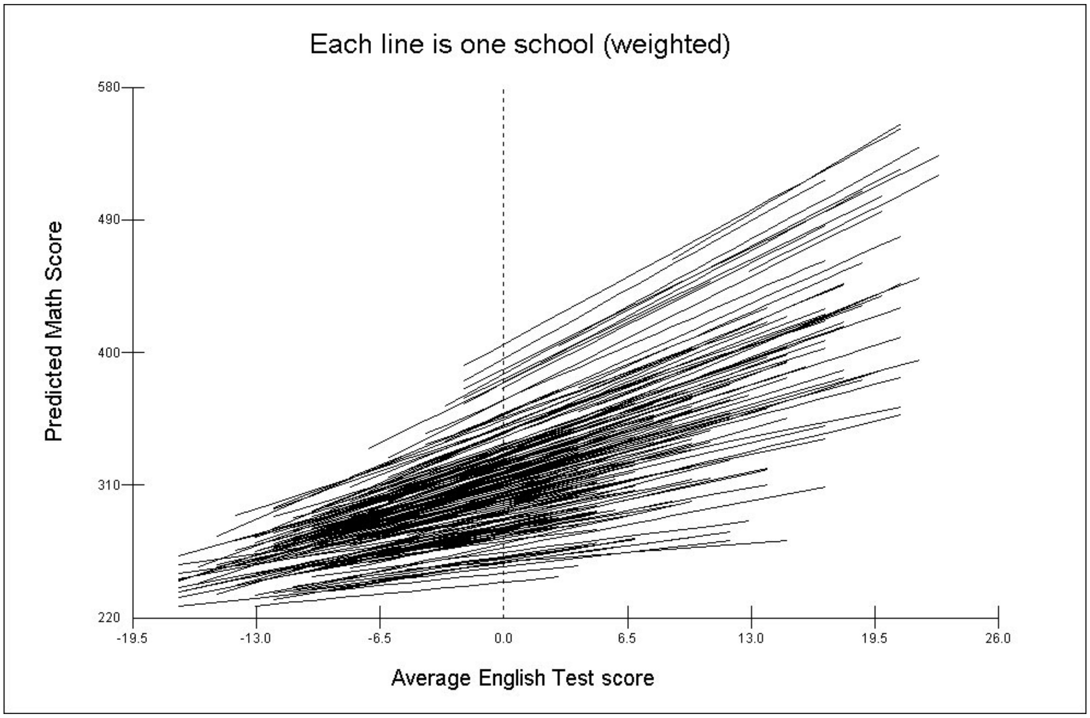
In conclusion, once all the predictors are added to the model, most of the school-level variance in pupils' achievement scores could be explained in the full model. This is not the case for the student-level variance as a large percentage of the variance on student level (50% of the 45% in the null model), could not be explained by the predictors (including a number of language related variables) used

in this model. This may be due to the fact that other variables that are not included in this study are important as well. For example, cognitive ability was not measured in this study as this has been shown by Van den Broek and Van Damme (2001) to explain in Belgium a great deal of variance on student level and to explain more than any other single variable in their multi-level model. More research is needed here.
However, the predictors did explain a high percentage of the variance between schools. This means that a large part of the differences between schools in pupils' mathematics achievement can be attributed to these variables. The full model indicates that significant predictors for how pupils in different schools perform in mathematics are the pupils' performance in the English test, the socio-economic status (to a lesser extent), the pupils' self concept, the pupils' perception of the importance of mathematics, their exposure to English, how pupils' maths teachers perceive their professional status, pupils' maths teachers beliefs about mathematics, the location of the school, the extent to which English is used in the classroom, the amount of time teachers spend working and the amount of time teachers spend in lesson planning. They are also significant predictors of how well pupils' perform in the same school (within-school variance), but to a lesser extent. Noteworthy is that two of these variables have a negative effect, teachers' perception of their status and their beliefs about mathematics. The stronger the teachers' ideas about mathematics and the perception about the status of the profession are, the poorer their pupils perform in mathematics. This observation should not be looked at in isolation, but in conjunction with the other variables that have a significant effect on mathematics achievement (see the discussion in Chapter 10).

The extension of the Student-School-Model

Random-Slope of AVER_ENG

Due to the amount of explained proportion variance on school level of *engtest*, it was decided to extend the student-school-model with random slopes (i.e. with a random slope for each school) of the average English test score (*engtest*). The results in Appendix 9.1 indicate that this model is a significant improvement of the full model (Model 15), as the deviation from the full model is highly significant ($p<.001$; see Appendix 9.1). Noteworthy is that the data of Model 16 show that the extension of the full model with random slopes results in it that *SES* is no longer significant. This means that the other school variables explain the variance in *SES* (as was concluded for *hlang* when discussing the full model). Another observation in the data of Model 16 is that the inclusion of the random slopes (i.e. per school its average value on *engtest* instead of taking the national average) results in lower estimates on all school variables, which shows that language proficiency is related to all school variables in another way.



Note: the mean of the English test score is 17.01.

Figure 9.2
Random slopes representing the predicted score on mathematics for each school (based on the English test scores)

Figure 9.2 shows the final model graphically extended with a random slope for each school on the English test (*engtest*) with the other axis representing the mathematics achievement score (resulting in Model 16).

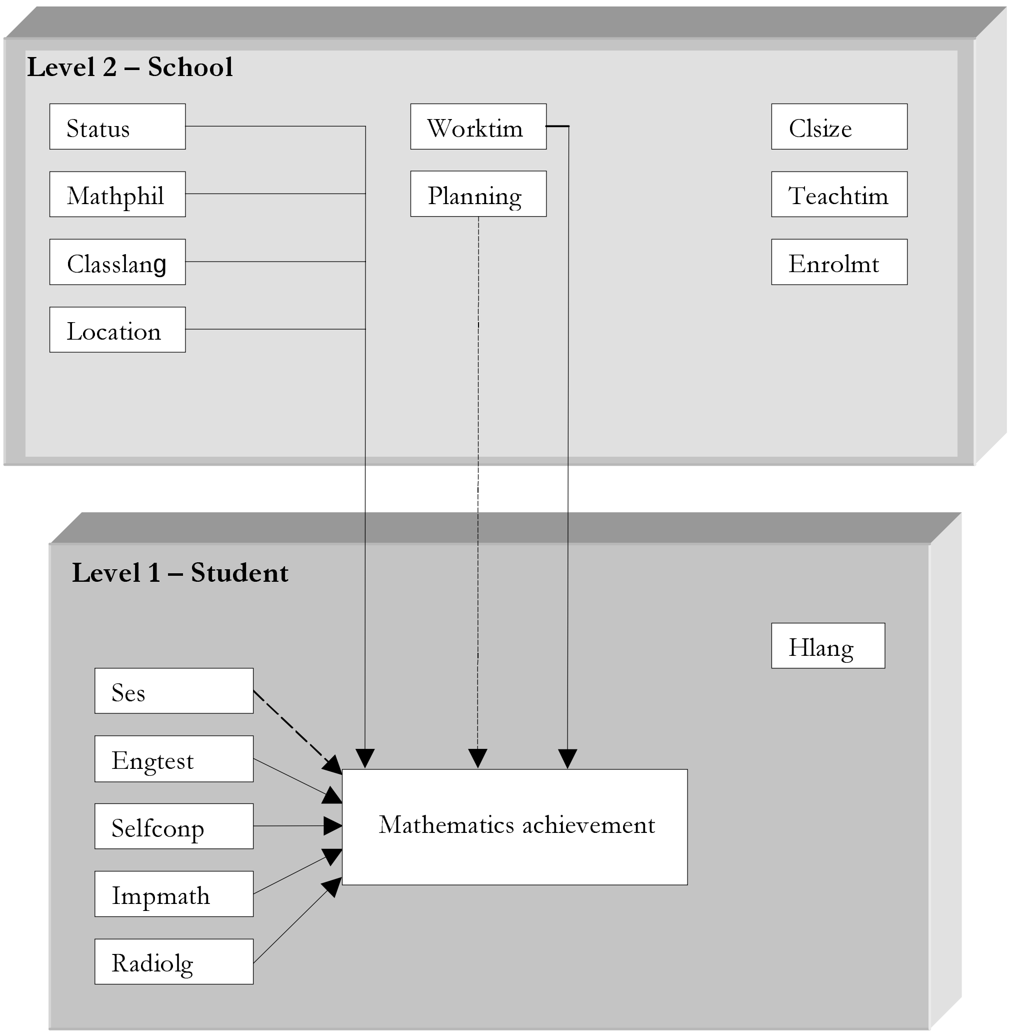
If one looks at the pattern of the slopes in Figure 9.2, it would appear as if the impact of the English test (*engtest*) on mathematics achievement is less in schools with a low average score on the English test. In other words schools where pupils did poorly in the English test, their proficiency hardly made any difference to their mathematics score. Conversely, the better that classes of pupils performed on the English Test, the stronger the relationship of this outcome was with mathematics. In other words, the correlation between the English test and the mathematics score is higher for schools with an on average high score on the engtest. There appears to be a curvilinear relationship between English and Mathematics, which means that language proficiency matters more when the English proficiency of schools is higher. Another observation should be made here. Figure 9.2 clearly shows that there are schools with a high average score on the English test and yet a low average performance on mathematics, combined with a low correlation between the two variables. This is an indication that there are in addition to English proficiency other variables (either within the model, e.g. location may be a candidate to investigate, or outside the present study) that are related to mathematics achievement. One possibility is that some informal tracking of pupils may be implemented at schools. So, there may be classes where the majority of pupils speak English at home, but may be grouped into a low ability mathematics class. Possible evidence of this practice was highlighted during the data collection for TIMSS-R where in at least six schools principals prevented field workers from testing the sampled class on the grounds that it was a low achieving group and insisted that the "A" class be tested. Pupils from these schools were subsequently withdrawn from the TIMSS-R sample. Clearly further research on this is needed to ascertain whether this or other reasons are responsible for the trend observed in Figure 9.2.

Interaction effects

As a final step in the multi-level analysis, an exploration was carried out whether an extension of Model 16 with interaction effects would result in a better understanding of the relationship between mathematics achievement and the predictor variables. A number of possible interactions were investigated, such as the location of the school with the performance of the pupils on the English test, as well as, the location with socio-economic status. Effects were also sought for the teachers' beliefs about mathematics with the pupils' self-concept in mathematics and also for teachers' beliefs about mathematics with pupils' perceptions about the importance of mathematics. However, no such effects were found in these explorations conducted within the framework of this research.

9.3 SUMMARY

In total 15 variables were included in the 2-level multilevel analysis, six on student-level and nine on school-level (see Figure 9.1).



Notes: ——— Confidence interval 99%
-------------- Confidence interval 95%

Figure 9.3
Final results of 2-level student-school model

In total, 11 of the 15 factors were found to be significant predictors of South African pupils' achievement in mathematics (see Figure 9.2 where enrolment, class size, teaching time and home language not being significant). In the starting model (null model) 55% of the variance of the pupils' scores is explained at school level and only 45% at the student-level. Once the student level model was attained, the model explained 61% of the variance on school-level and the 41% on student level. The final student-school model explained 78% of the school-level variance and only 50% on student-level. Once the school-level variables are introduced, the effect of home language (hlang), which was significant in the student model, lost its significance. The most significant factor was the English test score and this was highlighted in the final extended model where the strength of the effect could be clearly seen. The data of Model 16, which is the full model with random slopes for the English test, showed that the extension of the full model with random slopes results in it that *SES* is no longer significant. The strength and significance of the school-level variables compensated for the student variables resulting in home language and *SES* losing their significance in the multilevel analysis.

In conclusion, the strength of the language component represented in a number of variables that have strong effects on mathematics achievement is clear. Moreover, the dedication of the teacher matters with regard to their pupils' achievement and furthermore the location of the school is an important predictor of South African pupils' achievement in mathematics.

CHAPTER 10
Conclusions and Recommendations

For the first time in history international studies, which indicate comparative standing in pupil attainment are conducted and taken seriously by governments (Taylor & Vinjevold, 1999, p. 1).

The IEA's Third International Mathematics and Science Study (TIMSS 1994/1995) and its Repeat (TIMSS-R 1998/1999) had an unprecedented effect on mathematics and science education in South Africa. The study has been widely reported, studied and quoted in Ministerial and education policy circles as well as amongst academics, researchers and teachers in these fields. Most recently, the South African pupils' performance in TIMSS-R and its predecessor were discussed in the latest parliamentary report on improving the value of public expenditure in primary and second schooling in South Africa (Seekings, 2001).

South Africa is a multicultural and a multilingual society. Eleven official languages are recognised and include Afrikaans English, Ndebele Northern and Southern Sotho, Swazi and Tsonga, Tswana, Venda, Xhosa, and Zulu. The importance of all South Africa's languages is stressed in policy papers and at school-level the documents promote bilingualism at the very least but prefer that pupils should learn at least three languages. However, the reality is that this is a problem in the majority of schools where the language of instruction used and the mother tongue of the teachers and/or the pupils is different. This causes additional challenges and tensions within the education system at primary and secondary school especially.

Another challenge is to provide quality mathematics education for the South African society of whom about 6 million of the 38 million people are functionally illiterate and innumerate. The new government in 1994 had a tremendous task of merging the education administration and management systems of the former apartheid government. Initially, the Ministry of Education focused on dismantling apartheid structures and establishing a more equitable basis for the financing of education. A flurry of policy papers emerged amongst others, the White Paper, Education and Training in a Democratic South Africa: First Steps to Develop a New System

(February, 1995), The National Education Policy Act (NEPA) (RSA, 1996), The South African Schools Act (SASA) (1996), Further Education and Training Act (1998), Education White Paper 4 on Further Education and Training (1998) and the National Strategy for Further Education and Training (1999-2001), Employment of Educators Act (RSA, 1998), South African Qualifications Authority (SAQA) Act (RSA, 1995), Curriculum 2005 (C2005), (DoE,1997a).

Since the new government there has been a major school reform underway with significant redistribution of power to the new provinces and also to schools. The new government goals included access, equity, redress, quality, efficiency and democracy. The introduction of the South African Schools Act (1996) resulted in multiple schools models of the apartheid era reduced to only private and public schools. Corporal punishment, the traditional method of maintaining discipline in the school, was banned. Attending schools between the ages of 7 years and 15 years became compulsory. School governing bodies were established, which amongst others, had to determine the language policy of the schools within the national and provincial frameworks. The Act encouraged the growth of black enrolment in the former white schools by announcing and enforcing the fact that racism is unacceptable. Nonetheless the gap between affluent and poor schools is still large. Naturally, teachers want to go to better resourced schools and avoid those where textbooks are scarce, there are large classes, where there are no toilets and windows are broken or where schools are temporarily closed due to water or electricity bills not being paid. However, what is emerging is that the inequalities increasing run along class lines rather than racial lines.

A new curriculum was envisaged by for grades 1-9 and Curriculum 2005 (see section 2.3) was developed through an extensive process of participation and consultation and was released in 1997 (DoE, 1997a). It was considered by its developers as being one of the most progressive of such policies in the world. It was driven by principles of outcomes-based education, pupil-centred education and the critical outcomes of the NQF. It specified specific outcomes and standards of achievement across eight learning areas. These outcomes reflected a major change in what was supposed to be learnt in schools and it emphasised competencies rather than particular knowledge. However, the new curriculum was attacked from many quarters for several reasons, primarily due to the anticipated difficulty of implementing it in a system with so many under-prepared and under-qualified teachers. To date, the new curriculum has still not been implemented having been through reviews and is currently undergoing revision.

In South Africa the matriculation examination is the most widely used indicator for performance in the absence of any other. Insufficient numbers of South African pupils take the mathematics matriculation exam and the majority under-perform. The recent introduction of national assessments (grades 3, 6 and 9) mean that South Africa will have additional means of measuring the performance of the system in the future. Whilst there are several studies touching on or including the assessment of mathematics achievement, these have tended to be smaller scale and less comprehensive than this study, at least in South Africa, and none were found using a nationally representative sample as in TIMSS (the Third International Mathematics and Science Study) and its repeat TIMSS-R. South Africa has participated in a number of international studies namely, TIMSS and TIMSS-R (on secondary level) and MLA (Monitoring Learning Achievement*)* and SACMEQ (Southern African Consortium for Monitoring Educational Quality) on primary level. These have filled the void of information on national level in the areas of mathematics, science and language achievement, although the data from MLA and SACMEQ were not yet available in March 2002.

It is against this backdrop that this investigation provides a unique national insight into the performance of South African junior secondary pupils in the TIMSS-R mathematics tests. In this final chapter, the research questions and approach are briefly summarised (10.1). In 10.2, there is a discussion of what can be learned from this study. In 10.3, conclusions are drawn from the factors influencing achievement and the implications arising from this research as well as a number of recommendations for further research, policy making and practice are discussed. Finally a number of concluding remarks are made in 10.4.

10.1 SUMMARY OF RESEARCH QUESTIONS AND RESULTS

The *aim of this study* is *to describe and to explore the main factors influencing the performance of the South African pupils in the mathematics test of TIMSS-R*, the Third International Mathematics and Science Study-Repeat conducted under the auspices of the IEA, the International Association for the Evaluation of Educational Achievement. The first phase's objective was to describe the performance of the pupils in the mathematics test, the pupils' proficiency in English as well describing the background characteristics of pupils, teachers and schools to the extent measured by TIMSS-R and this was covered in Chapter 7. The objective of the second phase was to explore the factors (and their inter-relationships) relating to the pupils' performance and language proficiency in relation to the background information that was collected from the pupils, teachers and principals of the schools included in the study and this was dealt with in Chapters 8 and 9.

In conceptualising this research, the IEA research model and the Shavelson, McDonnell and Oakes (1987) were the basis upon which the conceptual framework for this research was based (see Chapter 5 and section 10.3 for more details).

The results according to the main research questions are as follows:

1. Who are the pupils, teachers and schools who participated in TIMSS-R?

South African *pupils* were on average older (15.6 years compared to 14.3 years) than their counterparts (see 7.3.1) and most of them attended schools where the medium of instruction (and hence of the tests) was different to the language spoken at home (see Table 7.20). A large percentage of South African pupils' parents had only finished primary school (see Table 7.23), and in more than two-thirds of the homes there were very few books (see Table 7.25). There were great differences in the SES backgrounds of the pupils and for instance less than two-thirds of the pupils come from homes with running water and slightly more than two-thirds have electricity in the home (see Table 7.28). South African pupils reported spending more time on mathematics homework than those internationally. The overwhelming majority of South African pupils found mathematics difficult and had a low self-concept with regard to mathematics although they were generally very positive about the subject (see Table 7.30). However, their aspirations were nonetheless higher than children internationally, as more than half wanted to study at university after school.

South African Grade 8 *mathematics teachers* (see section 7.4.1) were predominantly young males. Approximately one in four mathematics teachers were not formally qualified to teach mathematics and had not completed education beyond secondary school (see Table 7.35). It is not surprising therefore that many of the teachers lacked the confidence to teach mathematics. The majority of teachers had to teach large classes (about 50 pupils) in Grade 8 and they spent more time on administration than their counterparts in other countries. They spent considerably more time re-teaching topics that should have been covered in the lower grades. Teachers also spent more time discussing pupils' homework in class in contrast to Asian countries in particular. However, most of the pupils' teachers reported that they allocated less mathematics homework and less frequently than those internationally. A higher percentage of South African pupils had comparatively unrestricted use of calculators more frequently (see Tables 7.41 and 7.42). South African teachers also exhibited stronger pedagogical beliefs about mathematics than their peers internationally (see Table 7.36).

Approximately half the *schools* (see section 7.5) in the study were located in rural areas. The admissions requirements differed between schools (see Table 7.46). The most common criteria for admittance related to residence, date of application and academic performance. Almost all (99%) South African schools expected the parents to serve on committees whereas less than half of schools internationally had such an expectation (see Table 7.47). While the role of the governing bodies was clear according to the principals, namely the formulation of disciplinary policy, budget and hiring teachers, the role of the teacher in many schools was quite constrained; responsibilities were limited to the placement of pupils in classes, textbook selection and influencing the curriculum they deliver (see Table 7.50).

Several aspects affected the capacity of more than half of the schools. Resources were very limited in many South African schools compared to schools in other countries in the study, especially with regard to the lack of instructional materials (see Table 7.51 and 7.52). Other common problems affecting schooling and learning were high rates of absenteeism and skipping class and even injury to teachers and pupils in a small percentage of schools (see Tables 7.53-7.55).

2. How did South African pupils perform in the TIMSS-R mathematics test?

Overall, SA pupils achieved a low score of 275 points out of 800 scale points for the TIMSS-R mathematics test. Pupils from the Western Cape achieved the highest average score of 381 scale points, (see section 7.1.1). There was no difference in the scores of the boys and girls. Pupils that spoke the language of the test (English or Afrikaans) more frequently at home also appeared to attain higher scores on the mathematics test. White pupils' scores are substantially higher than those of other groups and the African pupils attained the lowest scores. However, the white pupils' mean score was nonetheless more than 100 points below the international mean score.

South African pupils' performance was relatively low in every mathematics content area (see Table 7.6). The average score for data representation, analysis and probability was the highest score of 356 points relative to the international average, although it was not included in the intended curriculum at Grade 8 level.

Pupils apparently had trouble with the interpretation of tables, figures and illustrations. They struggled with questions requiring more than one step and appeared unable to articulate their answers in writing. When faced with multiple-choice questions pupils resorted to guessing the answer. In conclusion, pupils could not communicate their answers in the language of the test and they lacked the basic mathematics knowledge expected at the Grade 8 level.

3. How does the performance of the South African pupils compare with pupils from other countries?

The South African mean score of 275 (standard error (SE) 6.8) was well below the international mean of 487 (SE 0.7) (see Figure 7.1). The result was significantly below the mean scores of all other participating countries, including the two other African countries of Morocco and Tunisia as well as that of other developing or newly developed countries such as Malaysia, the Philippines, Indonesia and Chile. Very few South African pupils (less than 0.5%) reached the top 10% benchmark, in contrast to Singapore where 46% of their pupils did. Only 1% of South African pupils reached the top 25% benchmark, compared to more than 60% of pupils from Japan, Hong Kong, Korea and Chinese Taipei and 75% of Singapore pupils. The top 25% of South Africa's pupils only achieved 337 points out of 800 (42%).

4. How does the performance of the South African pupils in 1998 compare with the performance of the South African pupils in 1995?

South Africa's overall score decreased by 3 scale points (see Figure 7.2), which was not statistically significant. In other words, there is no real difference in performance between the South African pupils in 1999 and those in 1995. Less than 0.5% of pupils in South Africa reached the top 10% in both 1995 and 1999. South Africa was the only country (out of 26) where this happened in both years.

5. How do pupils from different language groups perform in the mathematics test?

Pupils who spoke either English or Afrikaans at home achieved higher scores than those who did not and achieved 100 points above the national average. What is illuminating is that children that spoke other languages at home (for example, Greek, Portuguese, or Tamil) and therefore also learned in a second language, they scored only 20 points on average less than first language speakers. However, children speaking African languages at home attained 100 points less than the other group of second language speakers (see Table 7.8).

6. How did pupils perform in the English Language proficiency test?

An English language proficiency test was included that aimed to assess pupils' writing related skills and language usage in English (see Appendix 7.1). The overall mean score for the language test was 17 out of 40 (n= 8 349). In general, the scores for boys and girls were comparable. The average score is very poor in terms of the pupils' language proficiency. Pupils from the wealthiest and most urbanised provinces (Gauteng (20.86) and Western Cape (21.96)) attained the highest overall scores (see Table 7.10). Pupils from the Limpopo displayed a very low proficiency in English (on average 13.8). Native English-speakers achieved the highest scores, although the mean score is not high considering that they were writing a second-language test. Pupils from the African language group clearly struggled with the test and the low average score reflects that (see Table 7.13). The other second language groups (Afrikaans and other languages) performed relatively well in comparison to the English group.

7. What exposure to English do pupils who do not have English as main language have?

Just over half of the pupils watched stations where the African languages were more dominant than the others (see section 7.2.2) and only one-third watched predominantly English channels. Two-thirds of the pupils listened to radio stations where African languages were most prominent and only one-quarter listened to English stations. However, this is considerable given that less than 10% of the pupils had English as their main language. However, only 8.5% of the pupils listen to Afrikaans radio stations, although nearly a fifth has Afrikaans as a main language.

8. What are the factors that have been found in research previously conducted that influence pupils' performance in mathematics?

Internationally, research addressing factors related to achievement were found using data from Australia, Belgium, Ethiopia, Indonesia, Eastern Europe and the Netherlands, but most were found in the USA (see chapter 3). No studies were found either nationally or internationally that attempt to link English Language proficiency to mathematics achievement using such a comprehensive comparative dataset with data on pupil, class and school levels.

Studies regarding the effects of language on mathematics achievement (see section 3.3) were reviewed and appear to indicate the importance of language in achievement generally including mathematics. There seems to be sufficient evidence internationally and some evidence locally to warrant the assessment of language and its relationship to mathematics on a large scale in South Africa.

There were many factors found on student-, class- and school- levels to have positive and negative effects on mathematics achievement. From the literature, it was clear that classroom-level factors had a closer relationship achievement than those on school-level. Those factors discussed on *student-level* (see section 3.4.1) included: socio-economic status, books in the home, parental education, parents occupation, parental relationships, parental press, parent's self-concept, pupils' attitudes to mathematics, family size, jobs in the home, pupils' aspirations, peer group attitudes, pupils' self concept, self expectations, pupils' anxiety, enjoyment of mathematics, attitudes towards maths, cognitive ability, reading ability, gender, age, attitudes towards teachers, time spent on homework.

On classroom level *class-level* (see section 3.4.2), factors found in the literature were the learning environment, teacher's characteristics (including gender), teacher's personality streaming, instructional methods, computers, teachers' competence, teacher's confidence, education background, teacher's qualifications, teachers' methods, class size, time on task, disruptions in class, calculators, content coverage, and assessment.

Finally on *school-level* (see section 3.4.3) a number of factors have been investigated in previous studies. These included textbooks, teacher quality, time on task, leadership, organisation, management, decision-making, within-school hierarchy, communication, school size, professional development, location, commitment, and the controlled environment. In this study, only textbooks, time on task, leadership, decision-making, school size and location can be explored, as the other factors were not included in the data collection.

Some of the differences between factors influencing achievement in developed and developing countries were discussed briefly in 3.4.4. More recent findings in school effectiveness studies show that school-level factors influence achievement far less than do factors at the class-level. However, as this research is largely based in developed countries, the question remains whether this is also the case in less-developed nations. It was also suggested that that pupils' socio-economic background and other extramural factors play a more significant role influencing school achievement as a society becomes more industrialized. In contrast, the resources at schools are more likely to be more important in developing countries

9. What factors on school level, class-level and student level influence pupils' performance in mathematics?

To answer this question, firstly an analysis of the data was conducted applying Partial Least Square Analysis (PLS) to explore which factors or variables are influencing mathematics achievement and thereafter, multilevel analysis was applied in an effort to develop a model explaining these results. The full results are reported in chapters 8 and 9 whilst the methods are described in Chapter 6.

The main results of the PLS analyses are the following:

Student- level factors

Data pertaining to the students' home background, their personal characteristics, their aptitude and competencies were explored (see section 8.1). A high percentage of variance (50%) in the pupils' mathematics score was explained. Six factors were found to have a direct effect (see Table 8.4) on South African pupils' performance in mathematics, namely the pupils' proficiency in English, their own self concept in terms of mathematics, the language pupils spoke at home, their socio-economic status at home, and whether or not they, their friends and their mothers thought that maths was important and language of learning in the classroom.

School-only level factors

Some important aspects of school quality related to school leadership, parent involvement, school profile, physical resources, human resources, autonomy, learning environment and school administration were explored in the data from the school principal's questionnaire (see section 8.2). Two important antecedents related to the type of community and the home language of the student was included in the model. Sixty-two percent of the variance in the students' scores in mathematics could be explained by three factors at the school level (as can be seen in 8.1.3, Table 8.5), namely, the community where the school was located, the influence that the teachers union have on the curriculum and an aggregated student variable, the extent to which the pupils in the class spoke the language of instruction as their first language.

Classroom-level only factors

From the mathematics teacher questionnaire, a number of classroom level factors were also explored and these resulted in including the following factors in the model: teachers' gender, teaching experience, teachers' level of education, time spent on activities, lesson preparation, teaching load, time on task, teachers' attitudes, success attribution, teachers' beliefs, teaching style, resources, limitations, and class size (see 8.2.4). In total, this model (see 8.2.6; Table 8.14) explained 46% of the variance in the pupils' mathematics scores by seven factors - the teachers attitudes, their beliefs about mathematics, the extent of their teaching and other workload, the size of the class they are teaching, their gender, resources and their dedication towards lesson preparation.

Combined school-class level factors

The school level model and the class-level model were combined and the predictors of mathematics achievement were selected from both models and combined with four aggregated student level factors into one model (see 8.3). Therefore factors related to teachers' characteristics, pupils' home background, their aptitude, their attitudes, school quality, teaching requirements, curriculum quality and instructional quality were all explored in one model. Finally, six factors were found that had strong effects on pupils' achievement in mathematics and that explained 27% of the mathematics score (see Table 8.18). These were the location of the school, class size, the attitude of the teacher, teachers' beliefs about mathematics, the teachers' workload (including teaching) and their dedication toward lesson preparation.

The results of the multi-level analysis were as follows

From the Partial Least Square analysis, the following factors were identified and included into the multilevel analysis language pupils spoke at home, socio-economic status, pupils' English test score, pupils' own self concept in terms of mathematics, whether or not they, their friends and their mothers thought that maths was important, language on the radio they most often listen to, size of the class the teachers were teaching, community where the school was situated, language spoken most often in the class by pupils and teachers, teachers' beliefs about mathematics, attitude of the teacher towards the profession, teachers' dedication toward lesson preparation, teachers' teaching load and teachers' total workload. A final variable was included because it was believed to be important from a political perspective, namely number of pupils enrolled in a school (see Chapter 9).

Ultimately 183 schools and 7 651 South African pupils were included in the multi-level analysis. In the Null-model (see Table 9.2) more than half of the variance is situated on the school level (55%) whilst 45% of the variance can be situated on student level.

In total, 11 of the 15 factors were found to be significant predictors of South African pupils' achievement in mathematics (see Figure 9.2 where enrolment, class size, teaching time and home language are not significant). In the starting model (null model) 55% of the variance of the pupils' scores is explained at school level and only 45% at the student-level. Once the student level model was attained, the model explained 61% of the variance on school-level and the 41% on student level. The final student-school model explained 78% of the school-level variance and only 50% on student-level. Once the school-level variables are introduced, the effect of home language (*hlang*), which was significant in the student model (Model 6), lost its significance. The most significant factor was the English test score and this was highlighted in the final extended model where the strength of the effect could be clearly seen. The data of Model 16, which is the full model with random slopes for the English test, showed that the extension of the full model with random slopes results in it that *SES* is no longer significant. The strength and significance of the school-level variables compensated for the student variables resulting in home language and *SES* losing their significance in the multilevel analysis.

In conclusion, once all the predictors are added to the model, most of the school-level variance in pupils' achievement scores could be explained in the full model. This is not the case for the student-level variance as a large percentage of the variance on student level (50% of the 45% in the null model) could not be explained by the predictors (including a number of language related variables) used in this model. This may be due to the fact that other variables that are not included in this study are important as well. For example, cognitive ability was not measured in this study as this has been shown by Van den Broek and Van Damme (2001) to explain in Belgium a great deal of variance on student level and to explain more than any other single variable in their multi-level model. More research is needed here.

However, the predictors did explain a high percentage of the variance between schools. This means that a large part of the differences between schools in pupils' mathematics achievement can be attributed to these variables. The full model indicates that significant predictors for how pupils in different schools perform in mathematics are the pupils' performance in the English test, the socio-economic status (to a lesser extent), the pupils' self concept, the pupils' perception of the importance of mathematics, their exposure to English, how pupils' maths teachers perceive their professional status, pupils' maths teachers beliefs about mathematics, the location of the school, the extent to which English is used in the classroom, the amount of time teachers spend working and the amount of time teachers spend in lesson planning. They are also significant predictors of how well pupils' perform in the same school (within-school variance), but to a lesser extent. Noteworthy is that two of these variables have a negative effect, teachers' perception of their status and their beliefs about mathematics. The stronger the teachers' ideas about mathematics and the perception about the status of the profession are, the poorer their pupils perform in mathematics. This observation should not be looked at in isolation, but in conjunction with the other variables that have a significant effect on mathematics achievement.

The final model was extended with a random slope for each school on the English test (engtest). The results revealed that the impact of the English test (engtest) on mathematics achievement was less in schools with a low average score on the English test.

A curvilinear relationship was found between English and Mathematics, meaning that in general language proficiency matters more when the English proficiency of schools is higher. The graph also revealed that there were a number of high performing schools with lower mathematics achievement. One explanation for this anomaly is that these could be English medium schools where the class selected was a lower ability mathematics groups for although tracking is often not explicit in a school, it is well known that pupils are grouped into higher and lower ability groups especially in classes for mathematics and science.

In conclusion, the strength of the language component represented in a number of variables that have strong effects on mathematics achievement is clear. Moreover, the dedication of the teacher matters with regard to their pupils' achievement and the location of the school is further an important predictor of South African pupils' achievement in mathematics.

Some hypotheses tested

This study is highly descriptive and exploratory in nature, however as mentioned in Chapter 5 a couple of hypotheses based on the literature and on the TIMSS results of 1995 were tested.

At first, it was hypothesised that s*chool-level factors would play a more significant role* with regard to South African Grade 8 pupils' achievement in mathematics *than student-level factors*. More of the variance in the mathematics score could be explained on school-level than on student level. Furthermore, six of the predictors were found on school-level, although these were mostly class-level factors, compared to five student-level predictors. It was also observed that school-level factors were able to compensate for certain student-level factors such as home language and SES thereby removing their significance in the model when school level factors were inserted. It may be concluded from this study that the schools are to a large extent characteristic of the type of child attending. As was mentioned earlier, recent findings in school effectiveness studies show that school-level factors influence achievement far less than factors at the class-level, although this research was primarily based on developed countries. This could not be pursued or verified in the multilevel analysis given the fact that the class represented the school as only one class per school had been tested. To test this hypothesis, more than one class per school would have to have been tested.

Secondly, it was hypothesised that *pupils performing poorly in the English language test would also perform poorly in the mathematics test.* This was found to be the case and pupils who attained low scores on the English test were also more likely to do so on the mathematics test. However, there were schools where pupils who attained high scores on the English test achieved low scores on the mathematics and these were suspected to be native English-speakers, which would help to explain this outcome. It may also be said that both the English test and the mathematics test may be considered measures of cognitive ability, which partially explain the results. Studies have shown that cognitive ability is the strongest predictor of achievement in mathematics. No such test was included in TIMSS-R allowing one to make such an observation in this study, but this is an issue that should be further researched in the South African context.

10.2 DISCUSSION AND REFLECTION

This section discusses can be learned from this research. The first part is a *methodological* reflection addressing the extent to which the research approach has influenced the results. The second part is a more *substantive* discussion and reflection in which the main outcomes of the analyses are compared with results of other research on the same topic.

10.2.1 Some methodological reflections

The research reported here is primarily a secondary analysis of the South African TIMSS-R study. This means that the research was necessarily limited to what was available through the data collection, which is different to designing one's own study independently. The plans for the study reported here were developed when TIMSS-

R was in its final design stage. Therefore some national options could be added, but there were only limited possibilities of what could be added. Time was also a factor and given the rest of the items already included, it was decided to limit the number of new items concentrating on issues related to language and social background.

Reflecting on the results of this secondary analysis of the TIMSS-R data, it is important to realise that during the course of the design this study that piggybacked on TIMSS-R, a number of choices had to be made. One of the most important of these was the selection of an appropriate measure of English Language proficiency for second language speakers that could be applied in 30 minutes or less. Time constraint was a real factor given the length of time that the pupils already had to spend on completing the mathematics and science tests as well as a questionnaire. A review of candidate measures revealed that of those available they exceeded this time limit resulting in the decision to select a subtest of an instrument measuring English proficiency of second language learners. This test, despite concerns (addressed in Chapter 5) produced valid and reliable results. However, the possible shortcomings of the test are also noted and should be avoided in future research.

A list of factors at student, classroom and school-level was identified from the literature (see Chapter 3), however once the variables in the TIMSS-R dataset (including the South African national option) were analysed, it was clear that only a limited number were included in the questionnaires. On student-level, amongst those identified from previous studies that were not included in the TIMSS-R study were are parents' occupations, parental relationships, parents' self-concept, pupil anxiety, cognitive ability, reading ability and attitudes to teachers. Fewer exceptions were found at teacher level, but those that could not be included were issues related to the pupils' response to the teacher's personality and unfortunately content coverage in mathematics (due to problems with the data, the latter could not be retrieved). Quite a number of factors were identified on school level from previous research were not included in the TIMSS-R questionnaires. These included issues related to the school's organisation, management within-school hierarchy, communication professional development, commitment, and the controlled environment.

Although the variables included in the final multilevel analysis were selected on empirical grounds based on sound conceptual thinking, one of the variables was included for important and educational reasons even though it was not significant in the final PLS model. The size of the school is an important variable particularly as many schools are overcrowded and do not have sufficient classroom space for the number of pupils. The average class size of 50 is an indicator as most of the classrooms built are supposedly built to accommodate 30-40 pupils. The insufficient space has resulted in many pupils, particularly in rural areas being taught outside under trees.

One may conclude that there is a number of relationships between components that could not be found or tested given either the quality of data collected or the fact that no appropriate variables could be identified under the relevant components in the conceptual framework (see Figure 5.3) based largely on the literature. *So, although several of the predicted relationships could not be found in this study, this does not mean that they do not exist.*

The type of analyses applied in this study also had limitations as PLS was exploratory, but only permitted uni-level analysis, whilst multilevel analysis could analyse various levels of data simultaneously, but does not provide information on indirect paths. These two analytical methods were thus complementary and multilevel analysis was able to build significantly on what was found in the PLS analysis. However, whilst these complementary methods provided an understanding of the power of the variables, the results were not sufficient to generate a new conceptual model for understanding pupils' mathematics achievement.

Another observation during the study is that of quality of some of the variables. The challenge of an international comparative study is to design instruments that can be modified to suit individual countries' contexts, but remain comparable. What emerged during the course of this study was the difficulty in using some of the background variables for comparison. It would appear that there are variables, which are more valid locally (nationally) (e.g. number of adults in the home) or regionally (such as teachers' education), and that such variables are internationally not as valid cross-nationally as desired by designers of international comparative studies such as TIMSS-R. This is an issue that needs further research in order to capture some of the subtle, but important explanatory variables accurately.

In conclusion, given the nature of the research questions the exploration of the factors believed to be important in determining mathematics achievement and the type of analytical approaches used meant that the data was extensively mined. Despite some of the limitations, this study resulted in quite a number of interesting results that will be reflected upon in the next section in relation to the literature and the conceptual model for the study.

10.2.2 Conclusion regarding factors influencing mathematics achievement of South African pupils

In this section, an overview of the final factors that were analysed in the multilevel analysis is given in relation to findings from other studies. Both factors that appeared to be significant and the ones that are not significant in this study will be discussed. Thereafter a discussion of the meaning of the results for the conceptual model follows.

Student-level factors

Pupils' home language and achievement in mathematics

In the student-level PLS analysis, the home language had a weak effect on achievement, although being one of the stronger paths to achievement. This variable lost it significance in the final multilevel model, which means that school variables explain its variance. In similar studies, neither Afrassa (1998) nor Vari (1997) and Mohandas (1999) explored home language in relation to achievement. However, simply inspecting the descriptive statistics from other developing countries (see Mullis et al., 2000) suggests that pupils in countries such as Indonesia, Malaysia, Philippines and Singapore do not seem to be seriously disadvantaged by writing tests in their second or third language in mathematics, however it is not clear why this is.

Exposure to language of test

This variable had been inserted as a national option given the interest to explore the effect of language on achievement in mathematics. Even in the final multilevel analysis this variable was highly significant. This has not been explored in other studies using IEA dataset. This may have significant implications given the fact that 50% of South Africans live in rural areas, although a high percentage have radios in their homes. Clearly children who spend more time listening to radio stations that were in the language of the test (English or Afrikaans) also performed better in mathematics. Apart from the native-speakers, this informal way of learning the language apparently has some benefit for second language speakers.

Language proficiency

Throughout all the analyses conducted, this variable had a strong effect culminating in it being highly significant in the final student-school model (see Chapter 9). The English language test was a national option and no other country in the TIMSS-R or TIMSS 1995 study included it. No other international comparative study on secondary level has looked at the issue of language proficiency and mathematics achievement. On primary level, the MLA studies included English as one of the subtests. However, they were not concerned with relating language proficiency and mathematics achievement, but merely with assessing the level of language proficiency and the level of mathematics achievement without relating the two.

Socio-economic status

SES was a significant factor in the final multilevel model, although its significance lessened after the introduction of the school-level variables. This study confirms that there is a significant relationship to achievement, which lost only its significance in the full model with random slopes when school variables explained its variance. SES has been extensively written about and a number of studies found that it had a significant relationship to achievement. (Afrassa, 1998; Cherian, 1992; Hafner, 1993; Kohr, et al, 1989; Luyten, 1994; Maqsud & Klalique, 1991; Mohandas, 1999; Mullis, 1992; Smith, 1994; Sojourner & Kushner, 1997; Young, 1997). Three studies found that SES did not have an effect (Bode, 1993; Monyana, 1996; Wong, 1992).

Self-concept in mathematics

In this study, pupils' self-concept regarding mathematics was found to be highly significant in the final analysis. Pupils with a positive self-concept (in this study those with a negative score indicating that they don't find mathematics difficult for instance) achieved higher scores in the mathematics test. There have been a considerable number of studies investigating pupils' attitudes towards mathematics including issues of anxiety, enjoyment, and interest. In most studies, pupils' positive attitudes were matched by a corresponding performance. However, very few have concentrated on self-concept. Nonetheless, one study by Ma (1995) indicated that pupils with a low self-concept in mathematics tended also to be low performers in mathematics. Afrassa (1998) found that pupils that expressed more positive attitudes towards mathematics (including having a positive self-concept) were likely to be higher achievers and that this was consistent with previous Australian research findings. Mohandas (1999) found that attitudes (including self-concept) did not have an effect on mathematics achievement amongst the Indonesian pupils.

Relevance of mathematics/Attitudes towards mathematics

The fact that the mother, friends of the pupil and the pupil felt that mathematics was important was highly significant in determining higher achievement in mathematics in this study. Neither Mohandas (1999) nor Afrassa (1998) found that this attitude variable was important in their studies. However in Martin, Mullis, Gregory, et al.'s study (2000) of 18 countries and factors determining achievement, this variable formed part of an index representing pupils' attitudes towards mathematics. It was found to be significant predictor in only 4 of the 18 countries analysed, namely Canada, Netherlands, Slovak Republic and Sweden. In Vari's (1997) study of Eastern European countries in TIMSS this variable was not significant in a regional model. However in the individual model for the Czech Republic it had a direct effect on achievement, but not in the other countries (Hungary, Latvia, Lithuania, Romania, the Russian Federation, Slovak Republic and Slovenia).

Conclusion

In South Africa, pupils tended to achieve higher scores in mathematics when their language proficiency in English was higher and were more likely to attain low scores in mathematics when their scores on the English test were low. Those that spoke English or Afrikaans at home tended to achieve higher scores in mathematics. Alternatively, children from homes where African languages were used were more likely to achieve lower scores. Pupils from poor homes were also less likely to achieve high scores in mathematics as opposed to those from wealthier families, who were more likely to attain higher scores in mathematics. Pupils who were in classes where the language of learning was mostly the previously official languages of instruction were more likely to achieve higher scores as opposed to those who were not. Better performance in mathematics tended to be found amongst children who came from homes where the mother believed that mathematics was important and where the child and their friends concurred with this. Pupils who had a strong self-concept in mathematics and namely did not find it particularly difficult, did not believe that they were not talented in maths, that maths is not more difficult for them than for their classmates and believe that maths is one of their strengths were much more likely to achieve higher scores in maths.

School-level factors

School location

The location of the school was found to have a significant effect on South African pupils' mathematics achievement. Children in rural schools achieved lower scores than those in urban areas. Young (1997) found that Australian pupils in rural areas also achieved lower scores in mathematics. In the case of South Africa, it is not surprising given the remarks made by Hofmeyer and Buckland (1992) that African children in homelands and rural areas were educationally more disadvantaged than those in urban areas and this still appears to be the case 10 years later.

School and class size

School size (enrolment) had no significant effect on mathematics achievement and the literature was inconclusive on the relationship between school size and achievement (see Luyten, 1994). However in the Netherlands, small schools that operate multigrade classrooms result in low achievement (Blank et al, 1990, 83-96). Luyten's study of pupils from the Netherlands, Sweden and the USA using data from the Second International Mathematics Study (SIMS) revealed that school size was not significant in the USA, Swedish or Dutch models. In Vari's (1997) study, size (a latent variable comprising both school size and class size) had a direct effect on achievement in the Eastern European Regional model and the Lithuanian and Russian Federation models (but not the others).

In this study of South African pupils, whilst class size had a direct effect in the PLS model, it no longer had a significant effect in the final student-school model. This finding is also supported by Cohn and Ressmiller (1987), who found that class size did not consistently have an effect on achievement. Likewise, Bode (1994) found no effect in the study of American pupils using the SIMS data. However, Martin, Mullis, Gregory, et al. (2000) found that it was a significant predictor for eight out of the 18 countries using TIMSS data, namely Australia, Belgium (Fl), France, Iceland, Ireland, Netherlands, New Zealand and Sweden. It must be said though that these were all developed countries and in fact that none of the developing countries were included in their study. Afrassa (1998) in his study using Australian TIMSS data found that class size had weak direct effect on achievement, but Mohandas (1999) did not include class size in his analysis of Indonesian pupils.

Language of learning

Language of learning was found to be a significant predictor of pupils' achievement in South Africa. However, in the other studies conducting secondary analysis using TIMSS data (Afrassa , 1998; Martin et al., 2000c; Mohandas, 1999) no reference was made by researchers to this being a problem or having researched it. Nonetheless, there is sufficient evidence from other studies indicating that language does affect mathematics achievement (Austin & Dawe, 1983; Berry, 1985; Clarkson, 1991; Tatre & Fennema, 1995; and Young, 1997; amongst others). It is clear from this and other studies that when pupils are compelled to learn through a second language, this can become a serious obstruction in the pupils' learning process and that the final outcome may be negatively influenced.

Teacher preparation of lessons

The amount of time, that teachers spent preparing lessons after school was a significant factor in predicting the achievement of South African pupils in mathematics. This variable was not found amongst the literature. However, in South Africa this is an issue, which may be of relevance particularly in relation to teachers' competence and professionalism. Its absence from the literature is perhaps due to the assumption that if one is a professional teacher, then lesson planning is an important core duty in teaching. However, given the concerns and discussions about teacher competence in this country (see Arnott & Kubeka, 1997; Taylor & Vinjevold, 1999; amongst others) perhaps that assumption is flawed. In the studies conducted internationally, neither Martin, Mullis, Gregory, et al. (2000) nor Mohandas (1999) investigated teachers' preparation as a variable linked to achievement and Afrassa (1999) only looked at student level data. It would appear as if not much attention has been given to this issue.

Teachers' attitudes towards their profession

The fact that teachers felt appreciated by society and by their pupils was a highly significant, although negative predictor of South African pupils' achievement in mathematics. Both items were included in the international option section of the questionnaire and therefore several countries in the study opted not to include it. This curious result has not been found reported elsewhere and may be explained by some unique South African cultural characteristic (see 8.2.6).

Teachers' beliefs about mathematics

Strong beliefs[1] about mathematics, was a highly significant predictor of achievement amongst South African pupils indicating that the more teachers felt, for instance, that mathematics was a primarily formal way of representing the real world, the lower the scores attained by their pupils (see 8.2.4). A number of studies regarding teachers and their attitudes towards mathematics have been conducted (Chapin & Eastman, 1996; Dungan & Thurlow, 1989; Tooke, 1993) and found a positive relationship with achievement, but only Chapin and Eastman (1996) investigated teachers' beliefs about mathematics. Although Martin et al. (2000c) investigated

[1] These were the following: that mathematics is primarily a formal way of representing the real world; that mathematics is primarily a practical and structured guide for addressing real situations; if students are having difficulty an effective approach is to given them more practice by themselves during the class; that more than one representation (picture, concrete material, symbol set etc) should be used in teaching a maths topic; the mathematics should be learned as sets of algorithms or rules that cover all possibilities; and that basic computational skills on the part of the teacher are sufficient for teaching secondary school maths.

pupils' attitudes towards mathematics, they did not include teachers' attitudes or beliefs regarding mathematics. Mohandas (1999) also omitted this variable from his study. Certainly the interesting South African results warrant further investigation.

Teachers' total workload

The time spent by teachers in total (work time) at school was highly significant in predicting South African pupils' achievement. However, the actual time spent teaching (teaching time) was not significant in the final multilevel model. Whilst time on task is widely documented (see Bloom 1974; Bradford, 1995; Meyinsse & Tashakkori, 1995; Mudeliar, 1987; Mullis, 1991; Sedlacek, 1990; amongst others) the issue of the amount of time spent by teachers on working at the school and the time spent teaching is less well documented. Again, perhaps this is peculiar to South Africa (or perhaps other developing countries) that a system has allowed such a diversity of behaviour to occur where some teachers work at school for up to 10 hours a day, whilst others barely seem to arrive at school before disappearing off home to run a second business.

Conclusion

The influence of the location of the school in rural or urban areas on mathematics achievement is not surprising given the under-development in rural areas in South Africa. However, as 50% of South Africa's population live in rural areas, the fact that students attending school in rural areas perform worse in mathematics than those attending schools in urban areas should be of serious concern to the education and other authorities and policy-makers.

An interesting outcome was the strength of teachers' attitudes, beliefs and dedication as predictors of pupils' achievement. Teachers with strong mathematical pedagogical beliefs and who believed that mathematics is primarily a formal way of representing the real world; that mathematics is primarily a practical and structured guide for addressing real situations; if students are having difficulty an effective approach is to given them more practice by themselves during the class; that more than one representation (picture, concrete material, symbol set etc) should be used in teaching a maths topic; the mathematics should be learned as sets of algorithms or rules that cover all possibilities; and that basic computational skills on the part of the teacher are sufficient for teaching secondary school maths; were also those whose pupils were more likely to achieve lower results. This may mean that the teachers with stronger beliefs have less content knowledge and less understanding about the philosophy of mathematics perhaps due to their training or lack thereof. This may also result in teaching pupils through rote learning whilst reporting in a way that reflects the philosophy of the new South African curriculum, namely pupil-centred and problem-based teaching. On the other hand, teachers that had weaker beliefs may reflect a group of teachers who had good training, have a good content knowledge and have confidence in their preparation to teach, but stick to traditional teaching methods in contrast to those advocated by the new curriculum. Pupils of such teachers may have performed better on the TIMSS-R test, a test, which has been criticised by proponents of realistic mathematics in the Netherlands as too traditional in its design and content. Further investigation of teachers' beliefs in relation to pupils' achievement is needed. For instance, is it true that "weaker" teachers with stronger beliefs gave socially desirable answers in response to these questions? In relation to the first question it may also be possible that teachers who were trained in mathematics as a formal discipline subscribe to these beliefs as a result.

Teachers with feelings of being appreciated by society and their pupils were more likely to produce pupils with lower results. As interpreted in Chapter 8, this could be due to the fact that these are teachers in more rural areas who are highly regarded by their communities, as they are well educated compared to others in those communities. However, schools in these same communities are also poor and lack resources and pupils come from poor homes and have much exposure to the languages of learning than their urban counterparts. So, although teachers feel affirmed, they are also challenged by the conditions in their schools, which results in pupils attaining lower scores. On the other hand teachers who feel less affirmed work in better conditions in urban areas and where their pupils come from different background. Pupils in classes where the pupils and the teachers mostly interacted in the official media of instruction (English or Afrikaans) were more likely to achieve better results in mathematics. Teachers' commitment appears to play a key role in pupils' performance. Pupils whose teachers spent more time with work related activities at school tended to achieve higher results in mathematics, although the amount of time that, teachers spent actually teaching had no effect. Likewise, the amount of time that teachers spent preparing lessons resulted in pupils being more likely to achieve higher results.

The lack of effect of class size as a predictor of achievement confirms previous findings in studies of developing countries. In the case of South Africa, those classes with large numbers of pupils (on average 50 pupils) are also those at schools with poor conditions described earlier and therefore it is possible that a type of bottom effect is felt here and therefore, the effect of the actual number of pupils is slight.

These findings are significant against the background of the situation in many South African schools, particularly in those where there are African pupils taught by African teachers. In these schools the conditions are the worst: limited resources and facilities, large percentages of under-qualified teachers, pupils from poor socio-economic backgrounds and instruction occurs in a secondary language.

10.2.3 The results related to the conceptual framework

As indicated in 10.2.1, the research reported here is primarily a secondary analysis of the South African TIMSS-R study. Only a few options could be added to the design of the TIMSS-R study and many variables that were identified from the literature (chapter 3) were not included in the TIMSS-R instruments and the national options for South Africa. As a consequence, this study cannot be considered one that is testing the conceptual framework underlying the analyses reported in Chapters 8 and 9. Yet, in terms of the outcomes of the study and reflecting on the elements of the conceptual framework for the study (see Figure 5.3) this study yields some interesting conclusions about and modifications of this framework that will discussed in this section. First will be discussed how the findings of this study can be mapped onto the components of the conceptual framework (see Figure 10.1). Given the limitations of the design and of the analyses methods applied (see 10.2.1) the findings do not allow for immediate deductions about changes in the conceptual framework, but they result in a reflection how they may influence the interrelationship between the components of the framework.

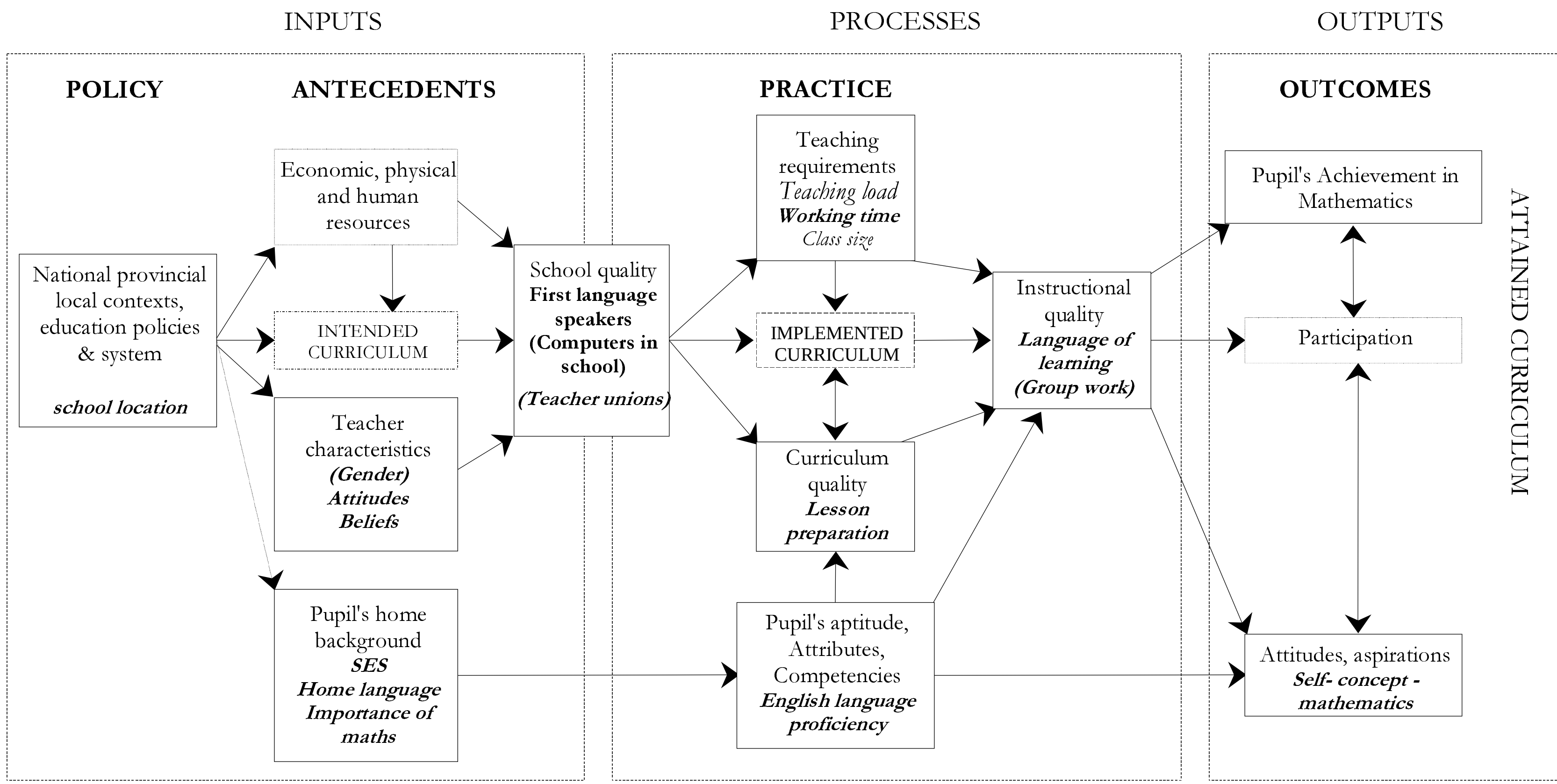
Figure 10.1 depicts how the factors resulting from the PLS and multi-level analyses can be located within the components of the framework. Some of the 19 factors were only significant in one or more of the PLS models, some were also significant in the final, combined PLS model, while again others appeared to be also significant in the final multi-level model.

In terms of the results, the role of the **input** variables (inputs into the education system) was an important one with eight of the 19 factors in the figure having a direct relationship with mathematics achievement and three others which were considered equally input and process variables under school quality (discussed below under 'process'). The location of the school which lies within the component "*national, provincial, local contexts…..*" was found to have a direct influence on mathematics achievement with pupils from urban areas achieving higher scores and be highly significant in the multilevel analysis. However no other factors were significant under this component.

No factors were found under the "*economic, physical and human resources* that were significant.

However, under *teacher characteristics*, the gender of the teacher, the attitudes of the teacher and the teachers' beliefs had a direct effect on achievement. However, the gender effect lost its significance in the final combined PLS model (see Figure 8.4), whilst attitudes and beliefs remained strong in not only the final PLS combined model, but also highly significant in the multilevel analysis (see Table 9.2).

A number of factors were also found amongst the *pupils' home background* that had a direct effect on achievement, namely home language, SES and attitudes about the importance of mathematics. Whilst SES, the importance of mathematics and radio language were significant in the multilevel analysis (the importance of mathematics and the radio language being highly significant), home language was no longer significant in the final multilevel model (see Table 9.2), despite having had a direct effect in the student-level model (see Figure 8.1).



Note: Factors in parentheses lose their effect in the final PLS models, Factors in italics have significant effects in final PLS models, Factors in bold are significant in final PLS and multi-level model.

Source: Howie, 2002, adapted from Shavelson et al., 1987.

Figure 10.1
Factors that have a direct effect on South African grade 8 pupils' performance in mathematics

An analysis of the factors found amongst **processes** in the model revealed that six had a direct effect on achievement in addition to the three mentioned earlier shared with "inputs". These three factors were found under the category of *school quality*, namely computers in the school, the number of children that spoke the official medium of instruction regarded therefore as first language speakers and the teachers' unions influence on the curriculum within the school. All three had had a direct effect on mathematics achievement with the number of first language speakers and unions appearing in the school-only model (see Figure 8.2) and the computers in the classroom-level model (see Figure 8.3). However, once the combined model was analysed, it was apparent that the computers in school had lost its direct effect and the first language speakers had been replaced with the aggregated student-level variable, language spoken in the home. A decision was made to drop the teacher union variable from further analysis given concern about the nature of the variable (see section 8.4.2).

Under *teaching requirements*, three factors were identified as having a direct effect on achievement. Class size and teaching load had a direct effect on mathematics achievement in both the classroom and the combined models, but were not significant in the final multilevel model. The amount of working time reported by the teacher had a direct effect not only in the classroom and combined models but was also highly significant in the final multilevel model.

Only one factor could be identified under *curriculum quality*, as unfortunately key variables such as the content coverage could not be analysed. Nonetheless, the amount of time spent by the teacher preparing the lessons was found to have a positive effect on their pupils' achievement and was significant in the final multilevel model.

Under *pupil's aptitude, attributes and competencies*, one very important factor was identified. The English language proficiency of pupils was strongly related to their mathematics achievement throughout and was highly significant in the final multilevel model.

There were two factors in the category of *instructional quality* that had direct effects on achievement. The language of learning (see Figure 8.1) and teaching style in the class (see Figure 8.3) had direct effects on achievement. However, whilst the language of learning remained highly significant in the multilevel model, teaching style lost its effect in the combined model and was not included for further in the multilevel analysis.

Finally, regarding the **outputs** of the education only one factor was found under the category of *attitudes and aspirations*. Pupils' self concept in mathematics had a direct effect on mathematics achievement (see Figure 8.1) and was found to be highly significant in the multilevel model (see Table 9.2).
Although various variables were analysed regarding *participation*, no effect was found on achievement. Although younger pupils and those with higher aspirations were more likely to participate in school, no relationship was found at the student-level between pupils' attendance and their achievement in mathematics.

Finally, the purpose of the study was not to confirm or dispute the conceptual framework, but rather to use the framework to conceptualise, categorise and to organise the variables to be use in an exploratory manner to identify relationships. Given the results, however, a number of possible additional relationships could be considered. For instance, starting with the inputs, a direct effect was found between school location in the *contexts and policies* component (which was added for the purposes of this study) and the school enrolment under *school quality*. Home language under *pupils' home background* had a direct effect on pupils' English language proficiency under *pupils' aptitudes, attributes and competencies* (this was also added for this study and was not included in the original Shavelson et al model). *Teacher characteristics* are related to *curriculum quality* as teachers' attitudes had a direct effect on lesson preparation. This suggests that whilst there may well be a relationship via school quality that teacher characteristics could be very influential particularly in exceptional circumstances where a motivated teacher is working in challenging circumstances, but perhaps this is a relationship generated in adverse circumstances more in keeping with a developing environment.

However, lesson preparation under *curriculum quality* had a direct effect on the English language proficiency under *pupils' aptitudes, attributes and competencies*. This relationship is possibly more indicative of the type of environment and the teachers in the school as a whole. *Pupils' aptitudes, attributes and competencies* in turn had a direct effect on pupils' self-concept in mathematics *(pupils' attitudes, aspirations*), which is a new addition to the original model. Teaching load, working time and class size all had a direct effect on *pupils' achievement in mathematics* and not via *instructional quality*. Instead, a direct effect was found between pupils' self-concept in mathematics (under *pupils' attitudes, aspirations*) and *pupils' achievement in mathematics* instead of via participation.

Finally, the limitation of the dataset may not necessarily be a weakness in the overall TIMSS-R study, however it is limiting to any secondary analysis when attempting to explain student achievement. The fact that the component *national, provincial, local* *contexts, policies and system* is largely empty of variables and that the *Economic, physical and human resources* component is not only empty of variables but is detached from the others in the model is an indication of the direction and interests of the study, but could also be reviewed as an opportunity for revisiting and reassessing the need to include factors linked to these components. Likewise the small number of process variables (on classroom level) is more of a concern where clearly as one comes closer to the student, more variance in the scores is explained. This may especially be the case in developing countries, where the context is clearly very different from the developed nations and this is particularly striking when reviewing available resources in the home for instance. This may well be the reason why schools do explain so much for the variance in the scores or are said to have a greater impact on pupils' scores in developing countries than the home background variables.

In conclusion, it can be said that the results are robust and to a large extent have validated what others have reported, albeit it internationally and not in South Africa. However, there are a number of issues that have been raised, for instance the curvilinear relationship between maths and English. This could only be ascertained applying PLS and MLN as correlations showed high relationship but did not reveal the complexity of the relationship. The results show that if the minimum language proficiency is missing then pupils cannot gain access to maths easily. One wonders what a test of all the home languages of the pupils would have revealed. For example, can one really improve English language proficiency of second language learners significantly if the home language is also not well established which is believed to be the case.

In South Africa, this study also revealed the close interrelationship of SES, home language, and language of learning in the classroom. This is largely due to the system of Apartheid, which divided people strictly according to race. This results in schools being characteristic still of race although in many areas this is changing fairly rapidly. In general, one can still characterise a school by SES and home language and that the former African schools are still attended almost exclusively by African pupils from poor SES backgrounds, who speak one of the African languages at home. As these pupils represent about 80% of the population, this remains the majority of schools in the country. For former coloured and Indian schools, the schools' demography is changing rapidly and becoming increasingly African in terms of the school population although the teachers are likely to remain coloured or Indian. In the poorer former white areas, these are becoming increasingly mixed (in particular the English medium schools) with children of all races to the extent that some schools have retained their white staff and have 80% or more African pupils. Government schools in wealthy neighbourhoods which were previously white areas still have mostly white pupils and pupils of other races who come from higher SES backgrounds. Many of the white pupils have moved to private schools (which have mushroomed over the past eight years) amidst (white) fears of falling standards and only the children of the wealthiest coloured, Indian and African parents are sent to these private schools, which are predominantly white and are taught largely by white teachers.

What has also occurred is the effect of families migrating across the country often in search of employment. It is not clear what effect that this has on pupils' learning and their language acquisition. For instance if a family moves from a rural area Eastern Cape where the home language is Xhosa to Johannesburg in Gauteng where all the official languages are found. However, it is highly unlikely that Xhosa will be spoken by teachers in the classes and pupils will be required to speak English or Afrikaans depending on the language in the class. If that same family moves again to the Northern province, then it is highly likely that teachers will switch from the official school language medium of English for example to Northern Sotho, which the pupil will have no access to. As yet, no large-scale systematic study of the effect of migration on pupils' learning or language proficiency has been conducted and yet it is becoming increasingly important given the shifting demographics in the country.

One issue of concern is that even the top-performing pupils in South Africa could not compete with the top pupils internationally and in some cases such as Singapore and Korea the top South African pupils did not even compare with the average pupils of those countries. Why is this the case and how does this happen where pupils do have the advantages of resources both at school and at home, and yet such a very small percentage of the pupils attain top marks internationally. Further investigation is needed into this issue.

10.3 RECOMMENDATIONS

TIMSS-R was the first international comparative study of mathematics education in secondary education in South Africa where the background variables could be explored on teacher and school level in addition to the student level in relation to achievement data. Therefore this research reported here is highly significant in the South African context, as this type of multi-level analysis has not been conducted previously in South Africa using this kind of data.

Therefore, given the size of the study, the richness of the results and the magnitude of the problems facing South African education it is appropriate that a number of recommendations are made based on the key findings of this research.
The results of both TIMSS studies show that the quality of mathematics education in South Africa is extremely low as compared to other countries in these studies. There is no evidence that the other school subjects in South African education are in a relative better state and certainly for science there is sufficient evidence (see Howie, 1996; Howie and Hughes, 1997; and Howie, 2001) to suggest that this is not the case. It is beyond discussion that the on-going efforts of curriculum reform can be seen as an important step. Nonetheless, given the result of the study reported here, there is little doubt that the implementation of the 'curriculum 2005' can only be successful if a 'broad band' strategy is applied that focuses on critical issues and aspects on all levels and components of the system; in other words a co-ordinated, well integrated and strategic *programme of action* is needed. Without claiming that this study provides the answers to all questions that can be stated about how to improve South African (mathematics) education, it is believed that the results of this study may provide a number of ingredients for such a programme.

In this section, key findings of this research are summarised followed by a number of suggestions and sometimes recommendations for improving policies and practices. The 'package' presented in this section is also informed by other studies and the knowledge of the South African context, and the whole should be considered as recommended 'ingredients' for the programme of action that should linked to the implementation of 'curriculum 2005'.

The key findings appear in the order largely generated by the research questions and not in terms of priority, each followed by suggestions or recommendations, sometimes phrased as key questions to be answered or implications to be addressed.

10.3.1 Recommendations and issues regarding pupils' achievement

Key Finding 1. South African pupils performed significantly worse than all the other participating countries in TIMSS-R including other developing countries.

Despite the fact that Morocco and Tunisia as well as that of other developing or newly developed countries such as Malaysia, the Philippines, Indonesia and Chile participated, South Africa still under-performed in comparison. How is it possible that the top South Africa pupils in a nationally representative sample performed the same as the average, or below average pupils, from other countries? This calls for a closer look at both the intended and implemented curricula to ascertain the reasons for this.

Firstly, high achieving pupils in mathematics and those with potential need to be identified and supported more so than is currently the case. This support should come from government, the schools, the community around the schools and from the private sector (as the future employers) This group needs to be expanded to represent the top 5-10% of the pupils in mathematics in the country and their talents developed in line with the top pupils internationally. Well-qualified, experienced and dedicated teachers, mathematics olympiads, mathematics clubs, projects, exposure to business and industry are important contributors to achieving this. Developing this pool of top achievers is critical as these are the future leaders in the sciences, engineering commerce and economics. Every country needs a critical mass of such talent and this should be seen as survival for the country and its economy rather than elitism. The alarming shortage of the youth entering into these fields has been discussed at several levels in the country for many years and a number of reports have been written. Despite this, the shortage remains and these results show that South Africa still has an dire and urgent problem to be addressed.

Secondly, Policymakers and education officials need to investigate why South African pupils lack the basic mathematics knowledge and skills expected at the Grade 8 level according not only to the standards set internationally, but also to those as set by the South African curricula. They need to ascertain why pupils struggled with complex questions and why they appeared answer questions requiring written answers and why the language proficiency levels in the language of the test are so low that pupils cannot articulate their answers in writing after pupils have been learning in this language medium for at least four years and learning the language for eight years? *These are difficult questions that have to be addressed, particularly as, pupils of other countries who are learning in a second language are apparently not as negatively affected by this as the pupils in South Africa.*

Key Finding 2. There is no significant difference in the performance between the South African pupils in 1998 and those in 1995.

No improvements occurred over four years despite the very low achievement in the first study (1995). This situation needs to be monitored carefully to track the quality of the education system. *Monitoring systems need to be put in place* in order to monitor trends over time. Given the fact that there is an attempt to implement a new curriculum, as well as a substantial effort to improve the conditions in schools, it is essential that the quality of the output of the system be monitored and evaluated.

Furthermore it is proposed that a large-scale longitudinal project be instituted from the first year of schooling that is aimed at *implementing a value-added system of monitoring.* This is important to ascertain at what level of development pupils are on entering schooling and to evaluate the contribution of the schools themselves. This is critical in so-called poor schools that have bad reputations since these schools inevitably end up with the weakest pupils from the poorest families resulting in low achievement, which cannot only be attributed to the schools themselves but also the circumstances of the pupils. Such a study would provide valuable information to the Department of Education and would illuminate the actual value that well-resourced and poor schools add to such pupils.

10.3.2 Recommendations and issues relating to language

Key Finding 3. Pupils who spoke either English or Afrikaans at home achieved higher scores than those who did not.

There is often a mismatch in many cases regarding the language of the pupil and the language of the teacher. With the increasing heterogeneity of South Africa's schools in culture and language, offering children the opportunity to learn in their own home language is becoming increasingly challenging. However, the difficulty of not being able to communicate fluently in a common language is leading to increased frustration for the teacher, disorientation on the part of the child, a slow rate of learning, disciplinary problems and teacher centred instruction. Although teachers are aware of the language policy they may have very different interpretations of it. The majority of parents, pupils and teachers perceive English as the gateway to opportunities more globally and therefore want the pupils to participate in their education through the medium of English.

The implementation of the language policy needs reassessing regarding it feasibility and the desires of the community. Unless, some hard decisions are taken, and quickly, by decision-makers, pupils and teachers will continue to struggle and pupils will under-perform in mathematics and other subjects. If, as the majority of parents seem to desire, English is increasingly used then the necessary support mechanisms need to be put into place including intensive language training of second language teachers who will be teaching through the medium of English. On the other hand, if however the decision is made to teach in mother tongue beyond grade 5, the ramifications are enormous considering that in urban environments, almost all the official languages are found. Segregating children and indeed teachers in terms of language (as clearly offering 11 languages of learning will be impossible within a single school) will be an enormous task and may reverse the cultural integration beginning to take place. Of course, in rural areas where one language is almost always clearly dominant, it is more feasible. The danger of considering in the language policy only one approach, albeit an important one, (for example only considering cultural identity or the political perspective); is that the multiple functions of schooling will be ignored. For, the curriculum and pupils' education have to fulfil the desires of society namely, that of educating them towards being a responsive citizen in a democratic society, of attaining certain basic knowledge and skills, being prepared for the workplace and/or further education and acquiring adequate social and interpersonal skills. *The government has to take a firm lead in finding the appropriate balance between these perspectives, as if this is left to the schools, the status quo will remain.*

Key Finding 4. The average English test score was very low and the majority of pupils' English language proficiency was poor.

Pupils speaking African languages had a very low English language proficiency as compared to other second language learners. Furthermore, there is no room for complacency as native English speakers as a group did not perform substantially better than the Afrikaans-speaking group given that this was an English second language test. As described above the low proficiency of second language speakers has a significant impact on the achievement of those learning through the medium of English. *It is clear that an urgent and intensive intervention is needed in both English as a discipline in the schools and as a medium of instruction. Above all, children need to be encouraged to read in their leisure time, but they also need to be given opportunities to write in English more so than presently so that they become familiar in articulating thoughts and knowledge in English and this should be targeted to all children, not only the second language speakers.*

Key Finding 5. In more than two-thirds of the pupils' homes there were very few books.

There needs to be an active national campaign to encourage children from a young age to read. This is line with a recommendation from an IEA study on reading literacy (Postlethwaite and Ross, 1992) involving 26 national educational systems. Children from poorer families need to have access to books through school and public libraries, and community centres. *It must become a priority to develop small libraries within all schools to allow children to read in their leisure time. Sufficient reading time must be allocated at school, and resources are needed in order to allow this.* This is critical if the policymakers are serious about reducing the illiteracy rates in the countries and to give second language children (in particular) opportunities to develop their skills in a second language.

Key Finding 6. Language of learning in the classroom was found to be a significant predictor of pupils' achievement in South Africa.

As has already been mentioned, many teachers lack the language fluency in the language of learning needed to adequately communicate with their pupils. *It is therefore recommended that in the pre-service teacher training, that the language of learning should form a core part of the training* than is currently the case and most especially for primary school teachers who have the first contact with the second language speakers in their developmental years. *It is also essential that all teachers are competent in another language which is dominant in the region and that this should be compulsory as part of the pre-service course.*

10.3.3 Recommendations and issues regarding teachers and teaching

Key Finding 7. Approximately one in four mathematics teachers were not formally qualified to teach mathematics and had not completed education beyond secondary school.

This study confirms what has been found in previous studies on teachers' qualifications. The continued practice of allocated unqualified teachers particularly in African schools is perpetuating the pupils continued poor performance and undermining teachers' confidence to teach mathematics adequately.

A follow-up evaluation of teacher qualifications in critical fields of mathematics and science at secondary level should be undertaken to assess the current national position as about seven years has passed since this was last undertaken. Furthermore, urgent attention to the training of mathematics teachers is needed as well as the need to *attract good quality trainees* into the profession. This can only be done if the status of teachers is enhanced which is linked to teacher professionalism and not only to salary scales. The *issue of bursaries* should be revisited to attract quality trainees into mathematics training specifically.

Key Finding 8. South African teachers spent considerably more time re-teaching topics that should have been covered in the lower grades than international counterparts.

This is a symptom of the malaise in the system as a whole and needs urgent attention. It is estimated that the pupils are at least two to three years behind in their content knowledge and skills by the time they reach grade 8 and this results in tremendous pressure on secondary school teachers. The sequencing of topics and the progression from one topic to another across grades needs reassessing. *It is recommended that systematic, regular monitoring and diagnostic testing be conducted on district or provincial level and less regularly (every 4-5 years) on national level* to identify problem areas and to target interventions timeously. *It is strongly recommended that this be introduced at the end of primary school (grade 7)* so that information is available for secondary school teachers about pupils have learned and how topics have been taught in primary school. Currently there is no system in place to do this effectively.

Key Finding 9. The more time that teachers spent preparing lessons after school, the better the South African pupils' scores in mathematics.

This is also an indicator of teachers' commitment to their profession and to their pupils. Unfortunately there is much anecdotal evidence of many teachers arriving at school without having prepared lesson plans and spending class time marking pupils' tests and homework. A professional teacher spends time planning lessons, preparing materials and has clear objectives in terms of the outcomes of the lessons. *It is clearly the task of the heads of departments in the schools as well as the district officials to monitor and evaluate teachers' preparation and teaching as part of the normal practice of a school and quality assurance for the education system. Visits by district officials have to be conducted without prior warning,* as it is inevitable that with warning all teachers would prepare for a particular lesson especially if they were to be visited officially. These visits should be conducted on a regular basis and lesson plans and pupils' workbooks should be evaluated to assess what work has been undertaken and whether lesson plans are actually implemented. Whilst this is part of the duties of the district offices, in many cases this does not happen. The heads of departments should supervise the planning of programmes for the terms and should monitor the classroom teaching on a regular basis in conjunction with the principal of the school.

Key Finding 10. Teachers pedagogical beliefs about mathematics, was a highly significant predictor of achievement amongst South African pupils.

It is clear that certain types of teachers carry with them certain kinds of beliefs. Whilst some of these are due to their experience at school, it is expected that they are largely due to their experiences in their further and higher education. It is also suspected that teachers who have no qualifications in mathematics will fall into the group of having strong beliefs that also exhibit certain misconceptions about the subject.

It is essential that in teacher training misconceptions about mathematics, are addressed thoroughly and that teacher trainees are provided with the opportunities to discuss the meaning and their conceptual understandings of mathematics.

Key Finding 11. The time spent by teachers in total at school was highly significant in predicting South African pupils' achievement.

Teachers work habits vary in the time they spend at school teaching and participating in other activities as well as the time spent preparing their lessons and marking and preparing tests. There are widespread reports of teachers absenteeism on pay days, leaving school grounds early, using class time to mark lessons and to study for their own studies and it is common practice to use about two months of the year to prepare and mark exam papers. During the data collection conducted by TIMSS-R in October 1998, many fieldworkers reported that the majority of pupils had already left school for the year and that teachers were absent. Although, it is now law that teachers have to be on the school grounds for seven hours a day, the reality is that often by early afternoon teachers have already left the school, not to mention those that arrive late.

It is essential that there is appropriate monitoring of teachers by principals and by district officials who should conduct unexpected visits to schools. Furthermore, unscheduled afternoon visits should be undertaken to ascertain whether or not teachers are at school for the mandatory period. *Teacher unions should also be involved* in order to inform their members and to support them concerning professional behaviour. Teachers found wanting should be held accountable for their behaviour and conversely*, teachers who perform outstanding work should be recognised for it and be seen as role models for others.*

10.3.4 Recommendations and issues regarding the curriculum

Key Finding 12. High rates of absenteeism and skipping class were found amongst South African pupils compared to pupils internationally.

Clearly exacerbating an under-resourced education is the lack of commitment of pupils to their own education. *A public campaign is needed to inform pupils and their parents of the importance of education for children's future and the future development of the country.* Certainly a much-overused cliché of "the culture of learning" is still highly relevant in this regard. In many schools, the culture of learning is absent. Children feel licensed to bunk school and classes when their teachers set this example and so the example has to be set by the teachers, principals and reinforced by parents at home. *Therefore, discipline in the school needs to be enforced, supported by accurately maintained registers of school attendance both for pupils and teachers, which should be checked regularly by district officials. Action against habitual offenders (pupils and teachers) should be taken and not ignored,* as it is clearly detrimental to the pupils' academic development and motivation.

Key Finding 13. South African pupils with a positive self-concept regarding mathematics achieved higher scores in the mathematics test.

Key Finding 14. Pupils' perceptions of the importance of mathematics is a significant predictor of mathematics achievement.

Pupils' self-concept regarding mathematics and their perceptions of the importance of mathematics are both significant predictors of mathematics achievement. It is logical that pupils who did not find mathematics difficult are more likely to be pupils who achieve higher scores in mathematics. However, there is a lot of anxiety about mathematics at school level and this is evident in the higher school grades as pupils try to avoid taking mathematics in the final years of school. Pupils often complain of mathematics being too abstract and detached from reality and therefore find it difficult. If pupils are able to see the relevance and therefore the importance of doing mathematics as a subject, they achieve higher scores.

If pupils are given the opportunity to learn mathematics in a situation closely linked to a real life situation given pupils' backgrounds and interests, then it is likely to make more sense to them. New ideas and skills have to be connected to pupils' experience and prior knowledge. If teachers can build on pupils' own methods and intuitive notions, this may help to design more meaningful instruction to the pupils.

Interventions are required at various levels. Firstly, at national level there should be a promotion of mathematics as an important subject (as is currently reflected in the White Paper 1995) and a popularisation of mathematics with the curriculum being seen as being more relevant.

Secondly, on school-level, teachers should ensure that their teaching is contextualised as much as possible by demonstrating the relevance of math for many real life situations *and that it becomes a challenging, but enjoyable experience for pupils.*

Thirdly, teacher (pre-service and in-service) training should prepare teachers for teaching in a different way.

Lastly, the assessment must be realigned in order to assess this adequately.

It is recognised that this presupposes both that teachers have adequate content knowledge to deal with various methods that pupils come up with, as well as, teachers being confident enough to allow pupils to take the lead in the classroom.

10.3.5 Other policy related recommendations and issues

Key Finding 15. South African pupils were on average older (15.5 years) than their counterparts by at least one year.

This has important consequences for the South African pupils as children from poorer homes especially that lack educational resources are increasingly disadvantaged the later they are admitted to school. These are the children who are most at risk throughout their school careers as their verbal, numerical and spatial development fall behind their counterparts from wealthier homes (often with more educated parents) who can often read and write by the time they enter school. The international trend is to enter the school at least by six years with some countries starting at five years and even four years. *Therefore, entry age is an issue that needs to be revisited by policymakers wishing to close the gap created by socio-economic circumstances and a lower age in line with international trends should be considered.*

Key Finding 16. Socio-economic status has a significant effect on mathematics achievement.

As in other countries, both developed and developing countries, children from poorer homes are more likely to achieve lower scores in mathematics. Whilst the South African government is sensitive to the importance of equity, with more than half of the population falling below the poverty line, this is a tremendous challenge to deal with. Where it is hardly feasible for the government to improve the lot of about 19 million people in the short-term, it may be possible to improve about targeted schools. *It is clear that if one is to offer children of the poor an opportunity to strive for social and economic progress then government education programmes have to focus in particular on schools in the poorest communities to attempt to achieve parity with other public schools.* Perhaps there is an opportunity in the deployment of teachers to ensure that these schools obtain the better qualified teachers, possibly even offering extra allowances for instance in remote areas or less desirable areas, and when allocating resources, to ensure that these schools have at least all the basic resources needed.

Key Finding 17. South African pupils poor performance may be influenced by teachers' low expectations.

It is believed that in general South African teachers' expectations of pupils, is too low (see Howie and Wedepohl, 1997) and that pupils become complacent with what they know and how much they need to know. South African pupils report that they like mathematics, that they do well in mathematics and that more pupils perceive mathematics to be easy than was the case of pupils from Japan and Korea who feel the opposite (see Shen, 2001). The academic standard within many South African schools is low and this combined with low expectations results in an environment, which is not challenging enough for pupils. This situation (low standards and low expectations) perpetuates pupils' over inflated opinions of their ability and lowers their motivation resulting in lower goals being set. The poor application of assessment by teachers within the classes is also contributing to this. Tasks are not cognitively demanding enough and teachers often focus the level on the weakest pupil. This is further exacerbated by the teachers own poor grasp of the mathematics content and the understanding of the nature of the discipline, which inhibits the quality of the instructional activities. The resulting lack of confidence in the mathematics topics spills over into the classroom with teachers controlling the instruction in a "chalk and talk" fashion.

Recommendation: *There is clearly a need for increased and intensive training for teachers in assessment methods and in particular in diagnostic assessment to allow them to utilise this to inform their own teaching.* Greater support needs to be given to teachers at all levels to assist them to resist accepting work of poor quality from pupils and to encourage them to raise their expectations of pupils as well as increasing pupils' expectations of themselves. *The education officials need to institute a culture of increased expectations of pupils by teachers and the community and this can also partly be addressed through pre-service training.*

Key Finding 18. Class size has no significant effect on achievement when all factors were considered.

Although the evidence of this study and others points to the fact that class size is insignificant with regard to the achievement of mathematics, any practicing teacher knows the difference between teaching 25 pupils as opposed to the average class size of 50 found in TIMSS-R. It is important to note that in developed countries an important reason for the same outcome is that low-ability children are often taught in smaller classes and mainstream pupils in larger ones. Furthermore, private schools versus pubic schools may exhibit another pattern. In SA there is most probably a combination or another dimension dominant.

However, a point of concern is that the School Register of Needs (SRN, 2000) reports on class sizes of 32:1 versus 15:1 in private schools. In the nationally representative sample of 200 schools where whole classes were selected, an average of 50 pupils in the mathematics classes were found.

The wide discrepancy in figures certainly requires further investigation, as two possibilities exist; the one being that there is a dire shortage of mathematics teachers resulting in large classes being formed, which is not being reported in the SRN. The other even less palatable one is that the SRN figures need reassessing. Either way, this warrants further investigation by the education authorities.

Key Finding 19. There is a lack of reliable national education indicators.

Finally, South Africa has very few indicators on national level with which to monitor and evaluate the quality of its education system. Whilst the Government is to be lauded on its effort to introduce assessment on grades 3,6 and 9, this is only part of what is needed. The fact that these are to be introduced in different years with the details unclear currently is cause for concern if one is striving for efficiency in such a system.

Recommendation: *Lack of national education indicators and quality measures should be addressed as a priority. This should include further research into fundamental factors, which affect South African pupils' achievement. Once identified, action should be taken to ensure that positive factors are implemented. There is a need for economic indicators, indicators regarding school processes as well as indicators on achievement of pupils.* This is in addition to the infra-structural information already collected although this is required as a normal part of any system for accounting purposes and ensuring that equity issues are addressed.

10.3.6 Recommendations for further research

The South African study of the TIMSS-R data induces a number of recommendations for further research. I fully agree with Seekings (2001, p. 104) when he states that ***"Skilled personnel all too often commit a huge amount of time to the collection of data but fail to spend enough time on the analysis thereof".*** This situation is often created by the very funders paying for the research, who will pay for an initial report within tight timelines containing the most basic analyses, but are reluctant to pay for more extensive data mining to excavate more substantial, more illuminating results. Hopefully, in the case of TIMSS-R mathematics results, this study goes partially to addressing Seekings' comments (see Seekings, 2001, p.104), but for further questions on the TIMSS-R data and certainly in the case of other available datasets it is important to act upon this.

In a number of cases the recommendations may pertain to research questions that imply just further (secondary) analysis of the TIMSS-R database, including the South African national options, but in a number of recommendations, research may be initiated this way but needs follow-up in new research designs and data collections. Finally, a few recommendations will be made for the design of international comparative achievement studies. As in the previous section, the recommendations for further research are linked to key findings of this study.

Key Finding 20. Other countries' second language pupils performed better than top performing South African pupils.

Several other countries had relatively large numbers of second language pupils and yet they performed as well as the first language pupils in their own country and better than top performing pupils in South Africa.

Recommendation: *Given the poor performance of South African pupils and in particular the difficulties exhibited by the second language pupils, further investigation may be helpful. Future research may firstly investigate why other countries show a different pattern and secondly explore whether the language variable in those countries shows similar patterns in relation to achievement as happened when school variables were added to the South African multilevel model (see Chapter 9). This research might reveal what lessons can be learned from this for South Africa.*

Key Finding 21. South African pupils whose teachers who feel appreciated by society and by their pupils achieve lower scores in mathematics than those who feel unappreciated.

This intriguing finding could be due to a combination of factors. There is the fact that these are teachers in more rural areas who are highly regarded by their communities, as they are well educated compared to others in those communities. However, schools in these same communities are also poor and lack resources and pupils come from poor homes and have much less exposure to the languages of learning than their urban counterparts. On the other hand, teachers, who feel less affirmed, work in better conditions in urban areas and where their pupils come from different backgrounds, a combination of factors that may result in higher achievement.

Recommendation: *This seemingly incongruous outcome needs to be further investigated as this relates directly to teachers' status as well as to attracting good quality trainees into the field of education.*

Key Finding 22. South African pupils achieved much lower scores on free-response items and had difficult in writing their answers.

The difficulty that pupils had with many of the mathematics items is a further motivating factor to explore the language proficiency of the pupils (in relation to achievement in subject areas) in greater depth.

Recommendation: *Firstly there needs to be a more detailed investigation of selected TIMSS-R mathematics items with regard to language issues to try to understand specific problems that pupils experienced with both the mathematics and the language of the items.*

This issue is related to the wider issue of the use of home language in education. There is substantial agreement of the value of the educational use of the home language and that there are dangerous effects of abandoning home language as a language of learning and teaching too early in favour of a language of higher status. There are cognitive, linguistic, affective, and social benefits of bilingual education especially through the additive bilingual education and these should be evaluated in the South African context.

Recommendation: *Secondly there is a need for a long-term large-scale project containing a number of experiments of different bilingual models in South Africa whilst the pupils' achievement in mathematics and other subjects is consistently monitored.*

Key Finding 23. Lessons from other countries.

International comparative studies serve to provide a mirror in which participating countries can review their performance. By providing comparative data on achievement and contextual variables, it is possible to get an overview and an insight into what other countries and systems are doing. After years of isolation, South Africa has obtained comparative measures against which it has been able to measure the quality of the outputs of its system. Many lessons can also be learnt from other education systems. For instance, South Korea provides one with an interesting case in point. The pupils from that country performed exceptionally well in both TIMSS and TIMSS-R although it is a moderate-income country (GNP $10 540) and it only spends 3.43% on its education. However, its monitoring system is one of the most rigorous of all TIMSS-R participating countries with national assessments occurring at each grade level in the system. The culture is such that educated people are very highly regarded and parents are anxious to receive and pay for education for their children at great sacrifice to themselves. Teachers teach large classes (on average 46 pupils) and are compensated for low salaries by high social status allowing South Korea to spend no more than 70% of its budget on teacher salaries. There are almost no drop-outs or repeaters in schools as every child is expected to perform both by parents and by schools. Consequently, absenteeism, late arrival and bunking classes are virtually unheard of and are completely unacceptable in that culture. The high performance of the pupils in Korea and the motivation of all in the system seems to be translating into a highly educated workforce and the emergence of an increasingly strong economy in that country. Perhaps from Korea despite all the cultural and other differences, South Africa may learn a number of relevant and valuable lessons.

Recommendation: *It is recommended that thorough study is made of the functioning of the educational systems of a carefully selected number of countries so that lessons can be learned from this for South Africa.*

Key Finding 24. There is an absence in the TIMSS-R study on processes within the school as well as an absence of information about school leadership.

The absence of this data leaves significant gaps in the explanatory variables available for secondary analysis.

Recommendation: *Given its mission and to allow for more thorough explanatory analysis of factors influencing achievement, it is recommended to the IEA to include these factors* in its future studies of mathematics and science achievement.

Key Finding 25. The need to investigate local, regional and cross-national validity.

In TIMSS-R some of the variables were found not to be strictly comparable across countries. The IEA may consider pursuing the issue of variables that have greater national or regional or cross-national validity and incorporate this into the design of their studies. It is believed that in international comparative achievement studies some variables may have a high cross-national validity whilst having a low local validity, whilst other variables have high local validity but actually a low cross-national validity (which TIMSS accommodates in some cases by having international options). Furthermore one may imagine that IEA study may increase in relevance by including also variables that are relevant for countries in a certain region (e.g. for Southern African Development Cooperation, SADC); see scheme.

	High	Low
Cross-national validity	X	-
Regional validity	X	X
Local validity	-	X

Recommendation: *So as to increase the relevance of IEA studies for participating countries, it is recommended that the IEA pays more attention to these validity issues when designing its studies.*

Encouraging national and regional options

IEA's international comparative studies offer an excellent opportunity for countries and regions to address their own national and/or regional interests through including additional items to be administered in their country. South Africa, amongst others should be alert to the opportunity to do this given the costs of collecting data nationally.

10.4 CONCLUSION

"*Too many South African children are sentenced to restricted opportunities in life because their teachers and principals and district officials are incompetent or worse, or because their schools lack crucial facilities, or because there are no books or other learning materials*" (Seekings, 2001, p. 187).

In the past few years, some progress has been made to address shortcomings in South African schools. These include additional classrooms being built resulting in pupil:classroom ratios dropping from 43:1 in 1996 to 38:1 in 2000. The number of schools with access to running water (65% in 1996 to 72% in 2000), electricity (42% in 1996 to 57% in 2000) and telecommunications (40% to 65%) increased. However, the number of schools having computers for teaching and learning remains small (only 12% in 2000). The effect of crime in schools is unacceptably high with 36% of the schools reporting criminal incidents and 3% of the schools reporting rape, murder and stabbing incidents.

Although significant progress has been made with regard to administrative restructuring, policy development and infra-structural improvements nonetheless, the quality of education that the majority of pupils are receiving is far from satisfactory. The study has highlighted the most significant predictors of mathematics within the scope of the data available and has raised a number of questions and issues that are believed to be pertinent to the future development of South African education, in particular in mathematics. The challenges abound within the education system of this country and in addition to the issues of access and equity the most important challenge awaiting is that of quality. Unless the level of education offered to the majority of pupils in the country is significantly improved and in general expectations of pupils by teachers and the community are increased, pupils will continue to perform to low levels as currently expected by the public. This vicious cycle of poor performance has to be broken starting with higher expectations of teacher behaviour, professionalism and training culminating in an established, secure and demanding school environment intolerant of incompetent principals, teachers and non-performing pupils.

REFERENCES

Abrami, P.C., Chambers, B., D'Appollonia, S. & Farrel, M. (1992). Group outcome: The relationship between group learning outcomes, attributional style, academic achievement, and self-concept. *Contemporary Educational Psychology*, *17*, 3, 201-210.

Adler, J. (1991). Into the future? An analysis of the working document for mathematics Std 2-4. In A. Olivier (Ed.), *Fourteenth National Convention on mathematics and science education*. *Mathematics proceedings*. University of Cape Town.

Afrassa, T.M. (1998). Mathematics achievement in the lower secondary school stages in Australia and Ethiopia: a comparative study of standards of achievement and student-level factors influencing achievement. Unpublished PhD. Thesis. Adelaide: Flinders University of South Australia, School of Education.

African National Congress (ANC) (1994). *A Policy Framework For Education and Training*. Education Department, ANC.

Aitken, M.A. & Longford, N.T. (1986). Statistical modelling issues in school effectiveness studies. *Journal of the Royal Statistical Society, A*, 149, 1-3.

Anderson, J.C. & Gerbing, D.W. (1988). Structuring equation modelling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103,* 3, 411-423.

Arnold, C.L. (1995). *Using HLM and NAEP data to explore school correlates of 1990 mathematics and geometry achievement in Grades 4, 8 and 12. Methodology and Results*. Washington: National Centre for Education Statistics.

Arnott, A. & Kubeka, Z. (1997). *Mathematics and science teachers: Demand, utilisation, supply, and training in South Africa*, Johannesburg: Edusource.

Asmal, K., 1999. *Statement in the National Assembly by the Minister of Education*, on the occasion of international literacy day, 8 September 1999.

Austin, J.L. & Howson, A.G. (1979). Language and mathematical education. *Educational Studies in Mathematics, No.10,* 161-197.

Baker, C. (1985). *Aspects of Bilingualism in Wales*. Clevedon: Multilingual Matters.

Baker, C. (1996). *Foundations of Bilingual Education and Bilingualism* (second edition). Clevedon: Multilingual Matters Ltd.

Baker, C. & Prys-Jones, S. (1998). *Encyclopedia of Bilingualism and Bilingual Education*. Clevedon: Multilingual Matters.

Baker, D. & Jones, D.P. (1993). Creating gender equality: Cross-national gender stratification and mathematical performance. *Sociological of Education, 66,* 2, 91-103.

Beaton, A., Martin, M., Mullis, I., Gonzalez, E., Smith, T. & Kelly, D. (1996). *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*. Chestnut Hill: Boston College.

Beaton, A., Mullis, I., Martin, M., Gonzalez, E., Kelly D. & Smith, T. (1996). *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study*. Chestnut Hill: Boston College.

Behutiye, N. & Wagner, J. (1995). *Some aspects of primary school pupils' cognitive development and their relationship to scholastic achievement*. Addis Ababa: Curriculum Evaluation and Educational research Division, Institute for Curriculum Development.

Benbow, C.P., Arjmand, O. & Walberg, H.J. (1991). Educational Productivity Predictors among mathematically talented students. *Journal of Educational Research, 84,* 4, 215-223.

Berhanu, B. (1986). *An investigation of the effect of family background on academic success of students in Menelik II secondary school and its psychological implications*. Unpublished BA thesis. Addis Ababa University, Faculty of Education.

Berry, J.W. (1985). Learning mathematics in a secondary language: Some cross-cultural issues. *For the learning of Mathematics*, *5*, 2, 18-23.

Bester, G. (1988). Die verband tussen die self-konsep van die wiskundeleerling en sy prestasie in wiskunde. *Suid-Afrikaanse Tydskrif vir Opvoedkunde*, *8*, 3, 165-169.

Birenbaum, M. & Gutvirtz, Y. (1993). The relationship between test anxiety and seriousness of errors in algebra. *Journal of Psychoeducational assessment, 11,* 1, 12-19.

Birenbaum, M. & Kraemer, R. (1995). Gender and Ethnic-group differences in causal attributions for success and failure in mathematics and language examinations. *Journal of Cross-cultural Psychology, 26,* 3.

Bishop, A. (1985). The social construction of meaning. *For the Learning of Mathematics*, *5*, 1, 24-28.

Blank, J.L.T., Boef-van der Meulen, S., Bronneman-Helmers, H.M., Herweijer, L.J., Kuhry, B. & Scheurs, R.A.H. (1990). *School en Schaal* (School and Scale). Rijswijk/Den Haag: Sociaal en Cultureel Planbureau/VUGA.

Blankley, W. (1994). The abyss in African school education in South Africa. *South African Journal of Science, 90*, 54.

Bloom, B.S. (1974). Implications of the IEA Studies for the Curriculum and Instruction. In A.C. Purves & D.U. Levine (Eds.), *Educational and International assessment. Implications of the IEA surveys of achievement*, pp. 65-84. Berkley, CA: McCutchen.

Bode, R.K. (1993). Hierarchical linear modelling of class ability range on student mathematics achievement. *Paper presented at a poster session at annual meeting of the American Educational Research Association, Atlanta, Georgia April 12-16.*

Bos, K.Tj. (2002). *Benefits and limitations of large-scale international comparative achievement studies: the case of IEA's TIMSS study*. Enschede: University of Twente.

Bos, K.Tj. & Kuiper, W.A.J.M. (1999). Modelling TIMSS data in a European comparative perspective: exploring influencing factors on achievement in mathematics in grade. *European Research and Evaluation: An international journal on theory and practice, 5*, 2, 157-179.

Bracey, G.W. (1991). Culture, class management, and math achievement. *Phi Delta Kappan*, *73*, 86.

Bradford, C**.** (1995). *Student outcomes and the professional preparation of Eighth-grade teachers in Science and Mathematics*. Research Report. Arlington, Virginia: National Science Foundation.

Brandon, P.R., Newton, B.J. & Hammond, O.W. (1987). Children's mathematics achievement in Hawaii: Sex differences favoring girls. *American Educational Research Journal*, *24,* 3, 437-461.

Brewer, D.J., Rees, D.I. & Argys, L.M. (1995). Detracking America's school. The reform without cost? *Phi Delta Kappan*, *77,* 3.

Brodie, K. (1989). Learning mathematics in a second language. *Educational Review*, *41*, 1, 39-53.

Brookhart, S.M. (1997). Effects of the classroom assessment environment on mathematics and science achievement. *The Journal of Educational Research*, *90,* 6, 323-330.

Brown, D. (1998*). Educational Policy and the choice of language in linguistically complex South African schools*. Durban: University of Natal, Education Policy Unit.

Bukowski, W.M., Hoza, B. & Boivin, M. (1993). Popularity, friendship and emotional adjustment during early adolescence. *New Directions for Child Development, 60*, 23-37.

Campbell, J.R. (1996). *PLSPATH Primer* (2nd ed.). New York: St John's Press.

Campbell, J.R. (1997). Early identification of mathematics talents has long-term positive consequences for career contributions. *Cross-national retrospective studies of mathematics Olympians,* 497-522.

Campbell, J.R. & Mandel, F. (1990). Connecting math achievement to parental influences. *Contemporary Educational Psychology*, *15*, 64-74.

Chapin, S.H. & Eastman, K.E. (1996). External and Internal characteristics of learning environments. *The Mathematics Teacher, 89, 2,* 112-115.

Chen, Y. Clark, T.B. & Schaffer, E.C. (1988). Teaching variables and mathematics achievement in the context of sixth grade classrooms in Taiwan. *International Review of Education*, *34,* 1, 115-124.

Cherian, V.I. (1992). *Family influences on scholastic achievement*. Inaugural address delivered on accepting the chair of Psychology of Education at the University of the North on 28 October 1992, Sovenga.

Cheung, K.C. (1988). Outcomes of schooling: Mathematics achievement and attitudes towards Mathematics learning in Hong Kong. *Educational Studies in Mathematics*, *19*, 2, 209-219.

Cheung, K.C. & Keeves, J.P. (1990). The problems with current analytical procedures. *International Journal of Educational Research 14, 3,* 233-244.

Chinapah, V., H'ddgui, E.M., Kanjee, A., Falajayo, W., Fomba, C.O., Hamissou, O., Rafalimanana, A. & Byamugisha, A. (1999). *Towards Quality education for All.* Pretoria: HSRC.

Chisholm, L. (2000). *A South African curriculum for the 21st century. A Report of the Review Committee on Curriculum 2005*. Pretoria: Department of Education.

Choppin, B. (1967). Social class and educational achievement. *International Study of achievement in Mathematics – A comparison of 12 Countries.* The Hague: IEA.

Clarkson, P.C. (1991). *Bilingualism and Mathematics Learning.* Australia, Geelong: Deakin University.

Clarkson, P.C. (1992). Language and mathematics: a comparison of bilingual and monolingual students of mathematics. *Educational studies in mathematics*, *23*, 417-429.

Cohn & Ressmiller (1987). Research on effective schools: Implications for less-developed countries. *Comparative Education Review*, *31*, 3, 377-399.

Cohen, J. (1969). *Statistical power analysis for the behavioural sciences*. New York: Academic Press.

Coleman, P., Campbell, E., Hobson, C., McPartland, J., Mood, A., Weinfeld, F. & York, R. (1966). *Equality of educational opportunity*: Washington DC.: National Centre for Educational Statistics.

Creemers, B.P.M. (1996). The school effectiveness knowledge base. In D. Reynolds et al. (Eds.), *Making good schools: linking school effectiveness and school improvement*. London: Routledge.

Creemers, B.P.M., Reynolds, D., Stringfield, S. & Teddlie, C. (Eds.) (2002). *World Class schools: further findings*. International School Effectiveness Research Programme. London: Routledge-Falmer.

Crouch, L. & Mabogoane, T. (1998). When the residuals matter than the coefficients: an educational perspective. *Journal of Studies in Economics and. Econometrics*, *22,* 2.

Cummins, J. (1981). The role of primary language development in promoting educational success for language minority students. In California State Department of Education (Ed.), *Schooling and language minority students. A theoretical framework*. Los Angeles: California State Department of Education.

Cummins, J. (1986). Empowering minority students: a framework for intervention. *Harvard Educational Review*, *56,* 1, 18-36.

Damtew, G. (1972). *Certain social factors affecting scholastic achievement of fifty Grade 5 pupils from Menelik II school.* Unpublished BA thesis. Addis Ababa University, Faculty of Education.

Daniel, D. (1995). School attendance and achievement among boys and girls: The case of selected grade six students in Addis Ababa. *Proceedings of the National Workshop on Strengthening Educational Research, Addis Ababa: Institute of Educational Research, Addis Ababa University*, 253-264.

Dawe, L. (1983). Bilingualism and mathematical reasoning in English as a second language. *Educational Studies in mathematics, 14*, 325-352.

De Leeuw, J. & Kreft, I.G.G. (1986). Random coefficient models for multilevel analysis. *Journal of Educational Statistics*, *11*, 57-86.

Department of Education (1995). *White Paper on Education and Training*. Government Gazette, Vol. 357, No. 16312. Pretoria: Government Printer.

Department of Education (1996). *The South African Schools Act*, Act 84 of 1996. Pretoria: Government Printer.

Department of Education (DoE) (1997a). *Curriculum 2005. Learning for the 21st Century*. Pretoria.

Department of Education (1997b). Language in Education Policy. Government Gazette, Vol. 17997, No. 383. Pretoria: Government Printer.

Department of Education (1998). *Further Education and Training Act*, *No. 98*. Pretoria: Government Printer.

Department of Education (1999). *Preliminary report of the 1998 Senior Certificate Examination*, Pretoria.

Department of Education (DoE) (2000). *National Examinations Report,* Pretoria.

Department of Education (2001a). *Draft revised National Curriculum Statement*. Pretoria.

Department of Education (2001b). *Education in South Africa: Achievements since 1994*. Pretoria.

Deresse, M., Wagner, J. & Alemaychu., M. (1990). *Factors affecting achievement of lower primary school pupils*. Addis Ababa: Institute of Curriculum Development and Educational Research.

De Villiers, A.P. (1997). Inefficiency and demographic realities of the South African school system. *South African Journal of Education, 17,* 2, 79-80.

Dickens, M.N. & Cornell, D.G. (1993). Parent influences on the mathematics self-concept of high ability adolescent girls. Special issue: Mathematics. *Journal for the Education of the Gifted*, *17*, 1, 53-73.

Dineen, P., Taylor, J. & Stephens, L. (1989). The effect of testing frequency upon the achievement of students in high school mathematics courses. *School Science and Mathematics*, *89,* 3, 197-200.

Dungan, J.F. & Thurlow, G.R. (1989). Students' attitudes to mathematics: a review of the literature. *Australian Mathematics Teacher*, *45,* 3, 8-11.

Dunkin, M. & Biddle, B.J. (1974). *The study of teaching*. New York: Holt, Rinehart and Winston.

Du Toit, D. (1991). A primary school mathematics curriculum for South Africa for the 21st century. In Olivier, A. (Ed.), *Fourteenth National Convention on mathematics and science education*: *Mathematics Proceedings*. Cape Town: University of Cape Town.

Edmonds, R. (1979). Effective schools for the urban poor. *Educational Leadership*, *37*, 15-24.

Education Foundation (1994, December). *Edusource Data News, 7*.

Education Foundation (1999, March). *Edusource Data News, 24*.

Ellerton, N.F. & Clements, M.A. (1991). *Mathematics in Language: A review of language factors in mathematics learning*. Australia, Geelong: Deakin.

Elley, W.B. (1992). *How in the world do students read?* The Hague: IEA.

Eshetu, A. (1988). *Comparative study of family background of high achievers and low achievers at Entoto technical, vocational and academic schools*. Unpublished BA thesis. Addis Ababa University, Faculty of Education.

Falk, F.R. (1987). *A Primer for Soft Modelling*. Berkeley: Institute of Human Development, University of California.

Falk, F.R. & Miller, N.B. (1992). *A Primer for Soft Modelling*. Akron, Ohio: the University of Akron Press.

Forje, J.W. (1998). Developing a science culture in Africa. In Pillay, P. & Prinsloo, C. (Eds.), *Science and technology and Africa*. Pretoria: HSRC.

Garcia, O. (Ed.) (1991). *Bilingual education*: *Focusschrift in Honour of Joshua A. Fishman*. Amsterdam/Philadelphia: John Benjamins.

Garcia, O. & Baker, C. (Eds.) (1995). *Policy and practice in Bilingual education*. Clevedon: Multilingual matters Ltd.

Garden, R. & Livingstone, I. (1989). The Contexts of Mathematics Edicationa: National, Communities and Schools. In D.F. Robitaille & R.A. Garden (Eds.), The IEA study of Mathematics II: Contexts and Outcomes of School Mathematics. Oxford: Pergamon Press.

Gardner, R.C. (1979). Social Psychological Aspects of Second Language Acquisition. In Giles & R. St. Clair (Eds.), *Language and Social Psychology*. Oxford: Blackwell.

Garofalo, J. (1989). Beliefs and their influence on mathematical performance. *Mathematics Teacher*, *82*, 502-505.

Gennet, (1991). Women in Education: *A study of academic performance and participation of female students in high schools of Addis Ababa*. Addis Ababa: Addis Ababa University, Department of Business Education, Faculty of Education.

Georgewill, J.W. (1990). Causes of poor achievement in West Africa School Certificate Mathematics Examinations in Rivers State secondary schools, Nigeria. *International Journal of Mathematics in Science and Technology*, *21,* 3, 379-386.

Giles, H. & Bryne, J.L. (1982). An intergroup approach to second language acquisition. *Journal of multilingual and multicultural development*, *3*, 10, 17-40.

Giles, H. & Coupland, N. (1991). *Language: Contexts and Consequences*. Milton Keynes: Open University Press.

Gliner, G.S. (1987). The relationship between Mathematics anxiety and achievement variables. *School Science and Mathematics*, *87*, 2, 81-87.

Goldstein, H. (1987). *Multilevel models in educational and social research.* London: Charles Griffith and Company Ltd.

Goldstein, H., Rasbash, J., Plewis, I., Draper, D., Browne, W., Yang, M., Woodhouse, G. & Healy, M. (1998). *A users guide to MLwiN*. University of London, Institute of Education, Multilevel Models Project.

Gordon, A. (1979). *Mental abilities, cognitive style and achievement in mathematics*. M. Ed Thesis. Johannesburg: University of Witwatersrand.

Gouws, E. (1997). Entrepreneurship education: an educational perspective, *SA Journal of Education*, *17*, 3, 143.

Gray, J., Hopkins, D., Reynolds, D., Wilcox, B., Farrell, S. & Jesson, D. (1999). *Improving Schools. Performance and potential.* Buckingham: Open University Press.

Greenwald, R., Hedges, L.V. & Laine, R.D. (1996). The effect of school resources on student achievement. *Review of Educational Research, 66,* 3, 361-396.

Hafner, A.L. (1993). Teaching methods scales and Mathematics-class achievement: what works with different outcome? *American Educational Research Journal*, *30*, 71-94.

Hartshorne, K. (1992). *Crisis and challenge: black education* 1910-1990. Cape Town: Oxford University Press.

Heck, R.H. & Thomas, S.L. (2000). *An introduction to Multilevel modelling techniques.* New Jersey: Lawrence Erlbaum Associates Inc. Publishers.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*, 1, 33-46.

Hensel, R.A.M. (1989). Mathematical achievement: Equating the sexes. *School Science and Mathematics*, *89,* 8, 646-653.

Heugh, K. (1999). Languages, development and reconstructing education in South Africa. *International Journal of Educational Development*, *19*, 301-313.

Heyneman, S.P. (1976). Influences on academic achievement: a comparison of results from Uganda and More industrial societies. *Sociology of Education*, *49*, 200-211.

Heyneman, S.P. (1986). The search for school effects in developing countries: 1966-1986, *Monograph of the World Bank* (Seminar paper series, no. 33).

Heyneman, S.P. & Loxley, W.A. (1983). The effect of primary school quality on academic achievement across twenty-nine high- and low-income countries. *American Journal of Sociology, 88*, 6, 1162-1194.

Hofmeyer, J. & Buckland, P. (1992). Education System Change in South Africa. In R. McGregor & McGregor, A. (Eds.). *McGregor's Alternatives*. Kenwyn: Juta's & Co. Ltd.

House, J.D. (1993). Achievement-related expectancies, academic self-concept and mathematics performance of academically under-prepared adolescent students. *Journal of Genetic Psychology*, *154*, 1, 61-71.

Howie, S.J. (1997). *Mathematics and science performance in the middle school years in South Africa: A summary report on the performance of the South African students in the Third International Mathematics and Science Study*. Pretoria: HSRC.

Howie, S.J. (1999). *Science content knowledge of first year science teacher trainees at colleges of education in South Africa***.** Unpublished M.Ed thesis. Johannesburg: University of Witwatersrand.

Howie, S.J. (2001*). Mathematics and Science Performance in Grade 8 in South Africa 1998/1999: TIMSS-R 1999 South Africa*. Pretoria: HSRC report.

Howie, S.J. & Hughes, C.A. (1998). *Mathematics and science literacy of final-year school students in South Africa: Third International Mathematics and Science Study*. Pretoria: HSRC.

Howie, S.J. & Pietersen, J.J. (2001). Mathematics Literacy of Final Year Students: South African Realities. *Studies in Educational Evaluation, 27,* 1, 7-26.

Howie, S.J. & Plomp, Tj. (in press). Mathematics Literacy of School leaving pupils in South Africa. *International Journal of Educational Development*.

Howie, S.J. & Wedepohl, P.T. (1997). The "crisis" in science and mathematics education in South Africa. *A paper presented at the British Educational Research Association conference, York, England, Sept. 1997.*

Hox, J.J. (1995). *Applied Multilevel analysis*. Amsterdam: TT-Publikaties.

Human Sciences Research Council (HSRC) (1990). *Achievement Test English Second Language Standard 6*. Ref. 2564/2. Pretoria: HSRC, Institute for Psychological and Edumetric Research.

Human Sciences Research Council (HSRC) (1991). *The De Lange report 10 years on*. HSRC Education Research Programme no. 24. Pretoria: HSRC.

Human Sciences Research Council (HSRC) (1997). *Schools needs based survey database*, HSRC Internal report. Pretoria: HSRC.

Husén, T. (Ed.) (1967). *International study of achievement in mathematics (Vol. 2).* New York: Stockholm, Almqvist and Wiksell, and Wiley.

Hyde, J.S. & Linn, M.C. (1988). Gender differences in verbal ability: a meta-analysis. *Psychology Bulletin*, *107*, 139-155.

Institute of Education (2000). *MLwiN: a visual interface for multilevel modelling. Version 1.10*. Multilevel Models project, University of London.

International Association for the Evaluation of Educational Achievement (2001). Third International Mathematics and Science Study 1998-9, South African Dataset.

Jacobs, J.E. (1991). Influence of gender stereotypes on parent child mathematics attitudes. *Journal of Educational Psychology, 83,* 4, 518-527.

Jansen, J.D. (1997). Why education policies will fail. *Indicator SA*, *12,* 56-58.

Jansen, J.D. (1999). The school curriculum since apartheid: intersections of politics and policy in the South African transition. *Journal of Curriculum Studies, 41,* 1, 57-69.

Janssen-Reinen, I.A.M. (1996*). Teachers and computer use: The process of integrating IT in the curriculum*. Enschede: Twente University Press.

Joint Education Trust (1998). Teaching in Multilingual Classes: a report of a literature survey commissioned by the Joint Education Trust (JET). *Joint Education Trust President's Education Initiative. Appendix C.* Johannesburg: JET/DANIDA.

Kahn, M. (1993). *Building the base: report on a sector study of science and mathematics education*. Pretoria: Commission of the European Communities.

Kaiser-Messmer, G. (1993). Results of an empirical study into gender differences in attitudes towards mathematics. *Educational Studies in Mathematics*, *25*, 3, 209-233.

Keeves, J.P. (1986). Aspiration, Motivation and Achievement: Different methods of analysis and different results. *International Journal of Educational Research*, *10*, 115-243.

Keeves, J.P. (1988). Path analysis. In J.P. Keeves (Ed.), *Educational research, Methodology and Measurement: An international handbook*, pp. 723-731. Oxford: Pergamon Press.

Keeves, J.P. (1992a). Missing data and non-response. In J.P. Keeves (Ed.), *The IEA Technical handbook* (pp. 261-270). The Netherlands, The Hague: IEA.

Keeves, J.P. (1992b). The IEA study of science III. Changes in Science Education and achievement: 1970-1984. Oxford: Pergamon Press.

Keeves, J.P. (1994*). The World of school learning. selected key findings from 35 years of IEA Research*. The Netherlands, The Hague: IEA.

Kika, F.M., McLaughlin, T.F. & Dixon, J. (1992). Effect of frequent testing of secondary Algebra students. *Journal of Research in Education*, *85*, 3, 159-162.

Klebanov, P.K. & Brooks-Gunn, J. (1992). Impact of maternal attitudes, girls' adjustment, and cognitive skills upon academic performance in middle and high school, *Journal of Research on Adolescence*, *2*, 1, 81-102.

Kotte, D. (1992). *Gender differences in science achievement in 10 countries*: 1970/71-1983/4. Frankfurt: Lang.

Kreeft, I. & De Leeuw, J. (1998*). Introducing Multi-level Modelling*. London: Sage publications.

Lambert, W.E. (1974). Culture and language as factors in learning and education. In F.E. Aboud & R.D. Meade (Eds.), *Cultural factors in learning and Education. Bellingham*, WA: 5th Western Washington Symposium on learning.

Lietz, P. (1995). *Changes in reading comprehension across cultures and over time*, New York: Waxmann.

Lockheed, M.E. (1990). *School effects on achievement in secondary Mathematics and Portuguese in Brazil*. Washington: World Bank.

Lockheed, M.E. & Komenan, A. (1989). Teaching quality and student achievement in Africa: the case of Nigeria and Swaziland. *Teaching and Teacher Education*, *5,* 2, 93-113.

Luyten, H. (1994). School size effects on achievement in secondary education: Evidence from the Netherlands, Sweden and the USA. *School effectiveness and school improvement, 5,* 1*,* 75-99.

Ma, X. (1995). The effect of informal oral testing frequency upon mathematics learning of high school students in China. *Journal of Classroom Interaction*, *30,* 1, 17-20.

Mackey, W.F. (1970). A typology of bilingual education, *Foreign Language Annuals*, *3*, 596-603.

MacDonald, C. & Burroughs, E. (1991). *Eager to Talk and Learn and Think. Bilingual primary education in South Africa.* Maskew Miller Longman: Cape Town.

Maja, B.I., du Plooy, J. & Swanepoel, Z. (n.d.). *Access to Learning: the enabling conditions for successful learning environments*. Unpublished.

Mandeville, G.K. & Liu, Q. (1997). The effect of teacher certification and task level on mathematics achievement. *Teaching and teacher education*, *13*, 4, 397-407.

Maqsud, M. & Khalique, C.M. (1991). Relationships of some socio-personal factors to mathematics achievement of secondary school and university students in Bophutatswana. *Educational Studies in Mathematics*, *22*, 4, 377-390.

Marsh, H.W. (1989). Sex differences in the development of verbal and mathematics contructs: the high school and beyond study. *American Educational Research Journal*, *26,* 2, 191-225.

Martin, M.O., Gregory, K.D. & Stemler, S.E. (2000). TIMSS 1999 *Technical Report: IEA's repeat of the Third International Mathematics and Science Study at the Eighth Grade.* Chestnut Hill: Boston College.

Martin, M., Mullis, I., Gonzalez, E.J., Gregory, K.D., Smith, T., Chrostowski, S.J., Garden, R.A. & O'Connor, K.M. (2000). *TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*. Chestnut Hill: Boston College.

Martin, M.O., Mullis, I.V., Gregory, K.D., Hoyle, C. & Shen, C. (2000). *Effective Schools in Science and Mathematics*. Chestnut Hill: Boston College.

Martin, M.O. & Kelly, D.L. (1996). *Technical Report. Volume1: Design and Development*. Amsterdam: IEA.

Mason, W.M. Wong, G.M. & Entwistle, B. (1983). Contextual analysis through the multilevel linear model. In Leinhardt, S. (Ed.), *Sociological methodology 1983-1984*: 72-103. San Francisco: Jossey-Boss.

Meece, J.L., Wigfield, A. & Eccles, J.S. (1990). Predictors of maths anxiety and its influence on young adolescents course enrolment intentions and performance in mathematics. *Journal of Educational Psychology, 82*, 1, 60-70.

Meyinsse, J. & Tashakkori, A. (1994). Analysis of Eighth graders' performance on standardised mathematics test. Paper presented at the Annual Meeting of the Mid-South meeting of Educational Research Association (Nashville, TN) November, 5.

Mohandas, R. (1999). *Mathematics and Science achievement of junior secondary school students in Indonesia*, Unpublished PhD. Thesis. Flinders University of South Australia, School of Education.

Monyana, H.J. (1996). *Factors related to mathematics achievement of secondary school pupils*. M. Ed. Thesis. University of South Africa. Unpublished.

Moodley, M. (1981). *A study of achievement in mathematics with special reference to the relationship between attitudes and attainment*. PhD. Thesis. Durban: University of Durban Westville.

Morrow, M. (1985). Some thoughts on the children's use of language in mathematics. *Lengwitch*: 7-14.

Mortimore, P. (1998). *The Road to improvement: reflections on school effectiveness*. Lisse: Swets and Zeitlinger.

Mpofana, W.S. (1989). *A didactical study of unsatisfactory classroom interaction as a factor related to the high failure rate in senior secondary schools in mathematics in KwaZulu*. Unpublished M. Ed. Thesis. Bloemfontein: University of the Orange Free State.

Mudeliar, K.M. (1987). *Factors affecting pupils' choice of and progress in mathematics at secondary school*. Unpublished M. Ed. Thesis. Johannesburg: University of the Witwatersrand.

Muller, J. & Roberts, J. (2000). *The sound and fury of international school reform: a critical review*. A report prepared for the Joint Education trust.

Mullis, I.V.S. (1991). *The state of mathematics achievement: NAEP's assessment of the nation and the trial assessment of the states*. Washington, DC.: GPO.

Mullis, I.V.S. (Ed.) (1992). *America's Mathematics Problem: Raising student achievement. A synthesis of findings from NAEP's 1992 mathematics assessment*. Princeton: National Assessment of Educational Progress.

Mullis, I., Martin, M., Gonzalez, E.J., Gregory, K.D., Garden, R.A., O'Connor, K.M., Chrostowski, S.J. & Smith, T. (2000). *TIMSS 1999 International Mathematics Report: Findings From IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*. Chestnut Hill: Boston College.

Munger, G.F. & Loyd, B.H. (1989). Gender and attitudes toward computers and calculators: their relationship to math performance. *Journal of Educational Computing Research*, *5,* 2, 167-177.

Newman, R.S. & Schwager, M.T. (1993). Students' perceptions of the teacher and classmates in relation to reported help seeking in math class. *The Elementary School Journal*, *94,* 3-17.

Nichols, J.D. & Miller, R.B. (1994). Cooperative learning and student motivation. *Contemporary Educational Psychology*, *19*, 2, 167-178.

Nimer Fayez, B. (1990). Mathematics anxiety, mathematics achievement, gender and socio-economic status among Arab secondary students in Israel. International *Journal of Mathematical Education in Science and Technology*, *21*, 319-324.

Noonan, R.D. & Wold, H. (1983). Partial Least Squares (PLS) – A statistical model for systems analysis. In H. Walberg. & T.N. Postlethwaite (Eds.), *Evaluation in Education*. An International Review Series. Vol. 7. pp. 269-290. Oxford: Pergamon Press.

Noonan, R.D. & Wold, H. (1988), Partial Least squares. In J.P. Keeves (Ed.), *Educational Research, Methodology and Measurement: An International Handbook*, pp. 710-716. Oxford: Pergamon Press.

Norman, C. (1988). Math Education: a mixed picture. *Science, 241,* 408-409.

Olivier, A., Murray, H. & Human, P. (1990). A constructivist approach to early arithmetic. In A. Olivier (Ed.), *Proceedings of the national subject didactics symposium, University of Stellenbosch*, 362-373.

Parcel, T.L., Nickoll, R.A. & Dufur, M.J. (1996). The effects of parental work and maternal non-employment on children's reading and mathematics achievement. *Work and Occupations*, *23*, 4, November, 461-483.

Pedhazur, E.J. (1982). *Multiple regression in behavioural research: Explanation and prediction*. New York: Holt, Rinehart, and Winston.

Pelgrum, W.J. & Plomp, Tj. (1991). *The use of computers in education worldwide*: *Results from the IEA computers in education survey in 19 education systems*. Oxford: Pergamon Press.

Pelgrum, W.J. & Plomp, Tj. (in press). Indicators of ICT in mathematics: Status and covariation with achievement measures. In D. Robitaille & A. Beaton (Eds.), *Secondary analysis of TIMSS data*. Oxford: Elsevier.

Pirie, G.H. (1984). Ethno-linguistic zoning in South African black townships, *AREA, 19*, 4.

Pizzini, E.L. & Shephardson, D.P. (1992). A comparison of the classroom dynamics of a problem-solving and traditional laboratory model of instruction using path analysis. *Journal of Research in Science Teaching*, *29*, 3, 243-258.

Plomp, Tj., Howie, S.J. & McGaw, B. (in press). International studies of educational achievement. In D. Stufflebeam & T. Kellaghan (Eds.), *The International Handbook of Educational Evaluation*. Dordrecht: Kluwer Academic.

Postlethwaite, T.N. & Ross, K.N. (1992). *Effective schools in reading: implications for educational planners*. Amsterdam: the International Association for the Evaluation of Educational Achievement (IEA).

Prinsloo, C., Kanjee, A, Pfeiffer, C. & Howie, S.J. (2001). *Baseline Study Technical Report. Teaching and Learning conditions*. Pretoria: HSRC.

Pyle, J. (1994). Gender composition and small-group learning in fourth grade mathematics. *Elementary Journal*, *94*, 5, 467-482.

Rakgokong, L. (1994). Language and the construction of meaning associated with division in primary mathematics. In M. Glencross (Ed.), *Proceedings of the Second Annual Meeting of the Southern African Association for Research in Mathematics and Science Education*. Umtata: University of Transkei.

Randall, T.M. (1990). Athletic self-concept and mathematics achievement in girls. *Psychological Reports*, *67*, 619-623.

Randhawa, B.S., Beamer, J.E. & Lundberg, I. (1993). Role of mathematics self-efficacy in the structural model of mathematics achievement. *Journal of Educational Psychology*, *85,* 41-48.

Raphael, D., Wahlstrom, M. & Mclean, L.D. (1989). School structure and its relationship to instructional methods and student outcomes in mathematics. *International Review of Education*, *34*, 1.

Raudenbush, S.W. & Bryk, A.S. (1986). A hierarchical model for studying school effects. *Sociology of Education*, *59*, 1-17.

Raudenbush, S.W. & Bryk, A.S. (1994). Hierarchical Linear Models. In Husén & Postlethwaite (Eds.), *International Encyclopedia of Education*, pp. 2590-2586. Oxford: Pergamon Press.

Republic of South Africa. (1953). *Bantu Education Act of 1953*. Pretoria.

Republic of South Africa. (1979). *Education and Training Act*. Pretoria.

Republic of South Africa. (1995). *South African Qualifications Authority Act*. Pretoria.

Republic of South Africa. (1996). *National Education Policy Act.* Government Gazette No. 27 of 1996. Pretoria.

Republic of South Africa (1998). *Employment of Educators Act.* Pretoria.

Reynolds, A.J. (1991). The middle schooling process: Influence on science and mathematics achievement from the longitudinal study of American youth. *Adolescence*, *26*, 101, 133-158.

Reynolds, A.J. & Walberg, H.J. (1992). A process model of mathematics achievement and attitude. *Journal for Research in Mathematics*, *23*, 4, 306-328.

Reynolds, D. (1998). World Class school improvement: an analysis of the implications of recent international school effectiveness and school improvement research for improvement practice. In A. Hargreaves et al. (Eds.), *International handbook of Educational Change,* p. 1279. Dordrecht: Kluwer Academic Press.

Reynolds, D. & Cuttance, P. (1992). *School effectiveness: research, Policy and Practice*. London: Cassell.

Riddell, A. (1997). Assessing designs for school effectiveness research and school improvement in development countries. *Comparative Education Review, 41,* 2, 178-204.

Robitaille, D.F. & Garden, R.A. (Eds.) (1996). *TIMSS Monograph No. 2: Research Questions and Study Design*. Vancouver: Pacific Educational Press.

Ross, K.N., Pfukani, P., Nzomo, J., Makuwa, D., Nassor, S., Kanyika, J., Machingaidze, T., Milner**,** G., Kulpoo, D., Postlethwaite, T.N., Saito, M. & Leite, S. (2000). Translating educational assessment findings into educational policy and reform measures: lessons from the SACMEQ initiative in Africa. *Paper presented at the World Education Forum, Dakar, Senegal, 26-28 April, 2000*.

Rutter, M., Maughan,B., Mortimore, P. & Outston, J. (1979). *Fifteen Thousand Hours.* London: Open Books.

Sammons, P. (1999). *School effectiveness: coming of age in the twenty-first century*. Lisse: Swets and Zeitlinger.

Sayers, R. (1994). Gender differences in mathematics education in Zambia. *Educational Studies in Mathematics*, *26,* 4, 389-403.

Schaub, M. & Baker, D.P. (1991). Solving the math problem: Exploring mathematics achievement in Japanese and American middle grades. *American Journal of Education*, *99*, 623-642.

Scheerens, J. (1998). The school effectiveness knowledge base as a guide for school improvement. In A. Hargreaves et al. (Eds.), *International handbook of Educational Change,* p. 1110. Dordrecht: Kluwer Academic Press.

Schiefele, U. & Csikszentmihalyi, M. (1995). Motivation and ability as factors in mathematics experience and achievement. *Journal for Research in Mathematics Education*, *26*, 2, 163-181.

Schmidt, W.H., McKnight, C.C., Valverde, G.A., Houang, R.T. & Wiley, D.E. (1997). *Many Visions, Many Aims. Volume 1. A cross-national investigation of curricular intentions in school mathematics*. Dordrecht: Kluwer Academic Publishers.

Schumann, J.H. (1978). *The Pidginisation Process: A model for second language acquisition*. Rowley, MA: Newbury House.

Scott, M. & Monteith, J.L. (1987). Differential contribution of personality to the explanation of variance in achievement in the first language and mathematics at high school level. *Psychology in the Schools*, *24*, 1, 78-83.

Sedlacek, D.S. (1990). *National assessment of educational progress, 1985-1986: mathematics achievement and classroom instructional activities.* Washington, DC.: US Dept of Education, Office of Educational Research and Improvement.

Seekings, J. (2001, December). *Making an informed investment: Improving the Value of Public Expenditure in Primary and Secondary schooling in South Africa*. Report for the Parliament of South Africa, commissioned by the Standing Committee on Public Accounts.

Sellin, N. (1989). *PLSPATH, Version 3.01 Application Manual.* Hamburg: University of Hamburg.

Sellin, N. (1990a). *PLSPATH, Version 3.01 Application Manual.* Hamburg: University of Hamburg.

Sellin, N. (1990b). On aggregation bias. In K.C. Cheung, J.P. Keeves, N. Sellin & S.C. Tsoi, The analysis of multivariate data in educational research: studies of problems and their solutions. *International Journal of Educational Research, 14*, 3, 257-268.

Sellin, N. (1991). *Statistical model building in research on teaching: The case of a study in eight countries*. Unpublished doctoral dissertation. Hamburg: University of Hamburg.

Sellin, N. (1992). Partial Least Squares path analysis. In J.P. Keeves (Ed.), *The IEA Technical Handbook*, pp. 397-412. The Hague: IEA.

Sellin, N. (1995). Partial Least Squares Modelling in Research on Educational Achievement. In Bos & R.H. Lehmann (Eds.), *Reflections on Educational Achievement: Papers in honour of T. Neville Postlethwaite,* pp. 256-267. New York: Waxmann.

Sellin, N. & Keeves, J.P. (1997). Path analysis with latent variables. . In J.P. Keeves (Ed.), *Educational Research, Methodology and Measurement: An International Handbook (2nd ed.)*, pp. 633-640. Cambridge: Pergamon Press.

Setati, M. (1999). Innovative language practices in the classroom. In N. Taylor & P. Vinjevold (Eds.), *Getting learning Right*. Johannesburg: Joint Education Trust.

Shavelson, R.J., McDonnell, L.M. & Oakes, J. (1987). *Indicators for monitoring mathematics and science education: a sourcebook*. Santa Monica (CA, USA): The RAND Corporation.

Shen, C. (in press). Revisiting the relationship between students' achievement and their self-perceptions: A cross-national analysis based on TIMSS 1999 data.

Shen, C. (2001). Social values associated with cross-national differences in mathematics and science achievement: A cross-national analysis, *Assessment in Education, 8*, 2, 198-223.

Signer, B., Beasely, T.M. & Bauer, E. (1997). Interaction of ethnicity, mathematics achievement level, socio-economic status and gender among high school students' mathematics self-concepts. *Journal of Education for Students placed at Risk, 2,* 4, 377-393.

Siskind, T.G. (1994). The effect of calculator use on mathematics achievement for rural high school students. *Rural Educator*, *16,* 1-4.

Snijders, T. & Bosker, R. (1999*). Multilevel analysis: an introduction to basic and advanced multilevel modelling*. London: Sage publications.

Sojourner, J. & Kushner, S.N. (1997). Variables that impact the education of African-American students: parental involvement, religious socialisation, socio-economic status, self-concept and gender. *Paper presented at the Annual Meeting of the American Education research Association. Chicago, Illinois, March 24-28*.

South African Institute for Race Relations (SAIRR) (1997). *South Africa 1996/7 survey*. Johannesburg: SAIRR.

Stern, H.H. (1983). *Fundamental concepts of language teaching*. Oxford: Oxford Press.

Tartre, L.A. & Fennema, E. (1995). Mathematics achievement and gender: a longitudinal study of selected cognitive and affective variables (grades 6-12). *Educational Studies in Mathematics, 28*, 199-227.

Taylor, N. (1988). Talk and writing: two distinct modes of doing mathematics. *Lengwitch*, March, 21-45.

Taylor, N. & Vinjevold, P. (Eds.) (1999). *Getting Learning Right*. Johannesburg: Joint Education Trust.

Teddlie, C. & Reynolds, D. (2000). *The International Handbook of School Effectiveness Research*. London: Falmer Press.

Tema, B. (1997). Classroom Practice in OBE. Jet Bulletin. No. 7, pp. 15-19.

Teshome, A. (1993). *A comparative study of academic achievement of students brought up under SOS children's village and under parental care at Higher 23 secondary School*. Unpublished BA thesis. Addis Ababa University, Faculty of Education.

Tocci, C.M. & Engelhard, G. (1991). Achievement, parental support and gender differences in attitudes towards mathematics. *The Journal of Educational Research*, *84*, 280-286.

Tooke, D.J. (1993). Student teachers' mathematical background and attainment of their secondary students. *The Clearing House, 66,* 273-277.

Tuijnman, A.C. & Keeves, J.P. (1994). Path analysis and linear structural relations analysis. In T. Husén & T.N. Postlethwaite (Eds.), *The International Encyclopedia of Education*, (2nd ed.), pp. 4339-4352. Oxford: Pergamon Press.

Travers, K.J. & Westbury, I. (Eds.) (1989). *The IEA study of mathematics I: Analysis of mathematics curricula*. Oxford: Pergamon Press.

UNESCO (1994). *United Nations Development Programme*. Paris: UNESCO.

UNESCO (1999). *Statistical Yearbook*, Paris: UNESCO.

Valas, H. & Sovik, N. (1993). Variables affecting students' intrinsic motivation for school mathematics: two empirical studies based on Deci and Ryan's theory on motivation. *Learning and Instruction*, *3,* 4, 281-298.

Van den Broek & Van Damme (2001). The effects of School, Class and Student characteristics on mathematics education in Flemish TIMSS-R data. *Paper presented at the European Conference on Educational Research, Lille, France*, *5-8 September*.

Vari, P. (1997). *Monitor'95. National Assessment of student achievement*. Budapest: National Institute of Public Education.

Vogt, W.P. (1999). *Dictionary of Statistics and methodology: a non-technical guide for the social sciences* (2nd edition). Thousand Oaks: Sage publications.

Webb, N.M. & Farivar, S.H. (1994). Promoting helping behaviour in cooperative small groups in middle school mathematics. *American Educational Research Journal, 31,* 369-395.

Webb, V. (1999). Multilingualism in democratic South Africa: the overestimation of language policy. *International Journal of Educational Development, 19*, 351-366.

West, M. & Hopkins, D. (1996). Reconceptualising school effectiveness and school improvement. *Paper presented at the American Educational Research Association Annual Meeting*, New York.

Wither, D. (1988). Influence on achievement in secondary school mathematics: Reporting research for teachers. *Unicorn*, *14*, 1, 48-51.

Wold, H. (1982). Soft Modelling: the basic design and some extensions. In K.G. Joreskog & H. Wold (Eds.), *Systems under indirect observation* (part II, Chapter 1). Amsterdam: North Holland.

Wong, N. (1992). The relationship among mathematics achievement, affective variables and home background. *Mathematics Education Research Journal*, *4*, 3, 32-42.

World Bank (1995). *Priorities and strategies for education*: A World Bank Review. Washington, DC.: The World Bank.

World Bank (1998). *World Development Indicators*. Washington, DC.: The World Bank.

World Bank (1999). *World Development Indicators*. Washington, DC.: The World Bank.

Young, D.J. (1997). A multilevel analysis of science and mathematics achievement. *Paper presented at the Annual Meeting of the American Educational Research Association in Chicago, Illinois, March 24-28, 1997.*

ENGLISH SUMMARY

English language proficiency and contextual factors influencing mathematics achievement of South African secondary school pupils

"For the first time in history international studies, which indicate comparative standing in pupil attainment are conducted and taken seriously by governments" (Taylor & Vinjevold, 1999, p. 1).

Introduction

The Third International Mathematics and Science Study (TIMSS 1994/1995) and its Repeat (TIMSS-R 1998/1999) both conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA), had an unprecedented effect on mathematics and science education in South Africa. The study has been widely reported, studied and quoted in Ministerial and education policy circles as well as amongst academics, researchers and teachers in these fields. Most recently, the South African pupils' performance in TIMSS-R and its predecessor were discussed in the latest parliamentary report on improving the value of public expenditure in primary and second schooling in South Africa (Seekings, 2001).

South Africa is a multicultural and a multilingual society. Eleven official languages are recognised and include, Afrikaans, English, Ndebele, Northern and Southern Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa, and Zulu. The importance of all South Africa's languages is stressed in policy papers and the documents promote bilingualism at school level at the very least but prefer that pupils should learn at least three languages. However, the reality is that this is a problem in the majority of schools where the language of instruction used and the mother tongue of the teachers and/or the pupils are different.

The new government in 1994 had a tremendous task of merging the education administration and management systems of the former Apartheid government. Initially, the Ministry of Education focused on dismantling apartheid structures and establishing a more equitable basis for the financing of education. A flurry of policy papers emerged amongst others, the *White Paper, Education and Training in a Democratic South Africa: First Steps to Develop a New System* (February, 1995), *The National Education Policy Act (NEPA) (RSA, 1996), The South African Schools Act (SASA) (1996*), *Further Education and Training Act (1998), Education White Paper 4 on Further Education and Training (1998)* and the *National Strategy for Further Education and Training (1999-2001)*, *Employment of Educators Act (RSA, 1998*), *South African Qualifications Authority (SAQA) Act (RSA, 1995*), *Curriculum 2005 (C2005),* (DoE,1997a).

Since the new government there has been a major school reform underway with significant redistribution of power to the new provinces and also to schools. The new government goals included access, equity, redress, quality, efficiency and democracy. The introduction of the South African Schools Act (1996) resulted in multiple schools models of the apartheid era be reduced to only private and public schools and encouraged the growth of black enrolment in the former white schools. Nonetheless the gap between affluent and poor schools is still large. What is emerging is that the inequalities are increasing and run along class lines rather than racial lines.

A new curriculum (Curriculum 2005) was envisaged for grades 1-9 (see section 2.3) and was developed through an extensive process of participation and consultation, and was released in 1997 (DoE, 1997a). However, to date, the new curriculum has still not been implemented, has been through reviews and is currently undergoing revision.

Insufficient numbers of South African pupils take the mathematics matriculation exam and the majority under-perform. Whilst there are several studies touching on or including the assessment of mathematics achievement, these have tended to be smaller scale and less comprehensive than this study, at least in South Africa, and none were found using a nationally representative sample as in TIMSS (1995) and its repeat TIMSS-R (1998). These have contributed to filling the void of information on national level in the areas of mathematics, science and language achievement.

Research questions and conceptual framework

The *aim of this study* is *to describe and to explore the main factors influencing the performance of the South African pupils in the mathematics test of TIMSS-R*, the Third International Mathematics and Science Study-Repeat conducted under the auspices of the IEA, the International Association for the Evaluation of Educational Achievement. The first phase's objective was to describe the performance of the pupils in the mathematics test, the pupils' proficiency in English as well describing the background characteristics of pupils, teachers and schools to the extent measured by TIMSS-R. The objective of the second phase was to explore the factors (and their inter-relationships) relating to the pupils' performance and to language proficiency in relation to the background information that was collected from the pupils, teachers and principals of the schools included in the study. In conceptualising this research, the IEA research model and the Shavelson, McDonnell and Oakes (1987) were the basis upon which the conceptual framework for this research was based (see Chapter 5).

The main research questions are as follows:

1. Who are the pupils, teachers and schools who participated in TIMSS-R?
2. How did South African pupils perform in the TIMSS-R mathematics test?
3. How does the performance of the South African pupils compare with pupils from other countries?
4. How does the performance of the South African pupils in 1998 compare with the performance of the South African pupils in 1995?
5. How do pupils from different language groups perform in the mathematics test?
6. How did pupils perform in the English Language proficiency test?
7. What exposure to English do pupils who do not have English as main language have?
8. What are the factors that have been found in research previously conducted that influence pupils' performance in mathematics?
9. What factors on school level, class-level and student level influence pupils' performance in mathematics?

Research design

The research is primarily a secondary analysis of the South African TIMSS-R study. This means that the research was necessarily limited to what was available through the data collection, which is different to designing one's own study independently. The plans for the study reported here were developed when TIMSS-R was in its final design stage. Therefore some national options could be added, but there were only limited possibilities of what could be added. Time was also a factor and given the rest of the items already included, it was decided to limit the number of new items concentrating on issues related to language and social background.

Statistical Package for Social Scientists (SPSS) was used for the descriptive statistics and the data preparation for the secondary analysis. Thereafter, Partial Least Squares analysis (PLS) was applied using PLSpath 3.01 and multilevel analysis was undertaken using MLnwiN1.10 to find answers to research question 9. These also had limitations as PLS was exploratory, but only permitted uni-level analysis, whilst multilevel analysis could analyse various levels of data simultaneously, but does not provide information on indirect paths. These two analytical methods were thus complementary and multilevel analysis was able to build significantly on what was found in the PLS analysis. However, whilst these complementary methods provided an understanding of the power of the variables, the results were not sufficient to generate a new conceptual model for understanding pupils' mathematics achievement.

Key Findings

From the descriptive analysis of 194 South African schools and 8 141 pupils the key findings were:

- South African pupils performed significantly worse than all the other participating countries in TIMSS-R including other developing countries.
- There is no significant difference in the performance of the South African pupils in 1998 and those in 1995.
- South African pupils achieved much lower scores on free-response items and had difficult in writing their answers.
- Pupils who spoke either English or Afrikaans at home achieved higher scores than those who did not.
- The average English test score was very low and the English language proficiency of the majority of pupils was poor.
- Other countries' second language pupils performed better than top performing South African pupils.
- South African pupils were on average older (15.5 years) than their counterparts (14.3 years) by more than one year.
- In more than two-thirds of the pupils' homes there were very few books.
- Approximately one in four mathematics teachers were not formally qualified to teach mathematics and had not completed education beyond secondary school.
- South African teachers spent considerably more time re-teaching topics that should have been covered in the lower grades than international counterparts.
- South African pupils whose teachers who feel appreciated by society and by their pupils achieve lower scores in mathematics than those who feel unappreciated.
- High rates of absenteeism and skipping class were found amongst South African pupils compared to pupils internationally.

The secondary analysis of 183 schools and 7 651 South African pupils revealed the following key findings:

On student-level

- Pupils' English language proficiency is highly significant in predicting a pupil's performance in mathematics with more proficient pupils achieving higher mathematics scores.
- Socio-economic status has a significant effect on mathematics achievement with pupils from wealthier backgrounds achieving higher scores.
- South African pupils with a positive self-concept regarding mathematics achieved significantly higher scores in the mathematics test.
- Pupils tend to achieve significantly higher scores if they, their friends and their mothers perceive mathematics to be important.
- The greater the pupils' exposure (by radio) to the language of the test, the higher the pupils' achievement in mathematics.
- When only student-level factors are considered, home language is significant, however, home language is not significant once certain school factors are taken into consideration.

On school-level

- School location is a significant predictor of pupils' achievement with pupils from more urban schools attaining higher scores.
- Language of learning was found to be a significant predictor of pupils' achievement in South Africa; and those classes where the language predominantly used was the same as the language of the test achieved higher mathematics scores.
- The more time that teachers spent preparing lessons after school, the higher the pupils' scores in mathematics.
- Teachers pedagogical beliefs about mathematics, was a highly significant predictor of achievement amongst South African pupils.
- The less appreciated (by the community and the pupils) teachers reported they feel, the higher the test scores of the pupils in mathematics.
- The time spent by teachers in total at school was highly significant in predicting South African pupils' achievement.
- Class size is *not significant* with regard to achievement when all other factors were considered.
- Teaching load was *not a significant predictor* of achievement when all other factors were considered.
- The size of the school was *not a significant predictor* of pupils' achievement in mathematics.

In the multilevel analysis more than half of the variance was situated on the school level (55%) whilst 45% of the variance can be situated on student level. The final model explained 78% of the school-level variance and only 50% on student-level. The strength of the language component represented in a number of variables that have strong effects on mathematics achievement is clear. Moreover, the dedication of the teacher matters with regard to their pupils' achievement and the location of the school is further an important predictor of South African pupils' achievement in mathematics

A curvilinear relationship was found between English and Mathematics, meaning that in general language proficiency matters more when the English proficiency of schools is higher. The graph also revealed that there were a number of high performing schools for English with lower mathematics achievement. One explanation for this anomaly is that these could be English medium schools where the class selected was a lower ability mathematics group for, although tracking is often not explicit in a school, it is well known that pupils are grouped into higher and lower ability groups especially in classes for mathematics and science.

Some hypotheses tested

This study is highly descriptive and exploratory in nature, however a couple of hypotheses based on the literature and on the TIMSS results of 1995 were tested.

It was hypothesised that s*chool-level factors would play a more important role* with regard to South African Grade 8 pupils' achievement in mathematics *than student-level factors*. In this study, more of the variance in the mathematics score could be explained on school-level than on student level. Furthermore, six of the predictors were found on school-level, although these were mostly class-level factors, compared to five student-level predictors. Recent findings in school effectiveness studies show that school-level factors influence achievement far less than factors at the class-level, although this research was primarily based on developed countries. This could not be pursued or verified in the multilevel analysis given the fact that the class represented the school as only one class per school had been tested. To test this hypothesis, more than one class per school would have to have been tested. In this study most variables that were used on school-level were in fact classroom. Therefore these findings lend some support to the hypotheses that classroom-level variables have more influence.

Secondly, it was hypothesised that *pupils performing poorly in the English language test would also perform poorly in the mathematics test*. This was found to be the case. It may also be said that both the English test and the mathematics test may be considered measures of cognitive ability, which partially explain the results. Studies in a number of industrialised countries have shown that cognitive ability is the strongest predictor of achievement in mathematics. No such test was included in TIMSS-R allowing one to make such an observation in this study, but this is an issue that should be further researched in the South African context.

From the picture emerging from the study, it is believed that in general South African teachers' expectations of pupils is too low and that pupils become complacent with what they know and how much they need to know. South African pupils report that they like mathematics and, that they do well in mathematics. Moreover, in South Africa more pupils perceive mathematics to be easy than was the case of pupils from high achieving countries of Japan and Korea who feel the opposite. The academic standard within many South African schools is low and this combined with low expectations results in an environment, which is not challenging enough for pupils. This situation (low standards and low expectations) perpetuates pupils' over inflated opinions of their ability and lowers their motivation resulting in lower goals being set. The poor and inappropriate application of assessment by many teachers within the classes is perhaps also contributing to this. Tasks are not cognitively demanding enough and the majority of teachers often focus the level on the weakest pupil. This is further exacerbated by the teachers own poor grasp of the mathematics content and the understanding of the nature of the discipline, which inhibits the quality of the instructional activities. The resulting lack of confidence in the mathematics topics spills over into the classroom with teachers controlling the instruction in a "chalk and talk" fashion.

Finally, it can be said that the results are robust and to a large extent have validated what others have reported, albeit it internationally and not in South Africa. However, there are a number of issues that have been raised, for instance the curvilinear relationship between maths and English and the strength of the relationship between the language variables and mathematics achievement. This could only be ascertained applying PLS and MLN as correlations showed high relationship but did not reveal the complexity of the relationship.

Conclusion

"Too many South African children are sentenced to restricted opportunities in life because their teachers and principals and district officials are incompetent or worse, or because their schools lack crucial facilities, or because there are no books or other learning materials" (Seekings, 2001, p. 187).

In the past few years, some progress has been made to address shortcomings in South African schools. These include additional classrooms being built resulting in pupil: classroom ratios dropping from 43:1 in 1996 to 38:1 in 2000. The number of schools with access to running water (+ 7%), electricity (+ 15%) and telecommunications (+ 25%) increased between 1996 and 2000. However, the number of schools having computers for teaching and learning remains small (only 12% in 2000). The effect of crime in schools is unacceptably high with 36% of the schools reporting criminal incidents and 3% of the schools reporting rape, murder and stabbing incidents (SRN, 2000).

Although significant progress has been made with regard to administrative restructuring, policy development and infra-structural improvements nonetheless, the quality of education that the majority of pupils are receiving is far from satisfactory. The study has highlighted the most significant predictors of mathematics achievement in South Africa at lower secondary level within the scope of the data available and has raised a number of questions and issues that are believed to be pertinent to the future development of South African education, in particular in mathematics. The challenges abound within the education system of this country and in addition to the issues of access and equity the most important challenge awaiting is that of quality. Unless the level of education offered to the majority of pupils in the country is significantly improved by expectations of pupils by teachers and in general the community are increased, pupils will continue to perform to low levels as currently expected by the public. This vicious cycle of poor performance has to be broken starting with higher expectations of teacher behaviour, professionalism and training culminating in an established, secure and demanding school environment intolerant of incompetent principals, and teachers and of non-performing pupils.

SAMENVATTING

Taalvaardigheid in Engels en contextfactoren van invloed op wiskunde-prestaties van Zuid-Afrikaanse leerlingen in het voortgezet onderwijs

"For the first time in history international studies, which indicate comparative standing in pupil attainment are conducted and taken seriously by governments" (Taylor & Vinjevold, 1999, p. 1).

Introductie

De Third International Mathematics and Science Study (TIMSS 1994/1995) en de herhaling ervan (TIMSS-Repeat of TIMSS-R 1998/1999), beide uitgevoerd onder auspiciën van de International Association for the Evaluation of Educational Achievement (IEA), hebben een ongekende invloed gehad op het onderwijs in wiskunde en de natuurwetenschappelijke vakken in Zuid-Afrika. De studie is breed gerapporteerd, geanalyseerd en geciteerd in kringen van zowel beleidsmakers, onderzoekers als onderwijspractici in die vakken. Recent zijn de prestaties van Zuid-Afrikaanse leerlingen in TIMSS-R en TIMSS besproken in het laatste parlementaire rapport over de verbetering van de opbrengsten van publieke middelen ten behoeve van het primair en secondair onderwijs in Zuid-Afrika (Seekings, 2001).

Zuid-Afrika is een multiculturele en veeltalige samenleving. Er zijn elf officiële talen, te weten Afrikaans, Engels, Ndebele, Northern en Southern Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa en Zulu. In veel beleidsdocumenten wordt het belang van deze talen benadrukt. Zo wordt in beleidsstukken tweetalig onderwijs genoemd als een minimumvoorwaarde waaraan scholen moeten voldoen, maar tegelijkertijd wordt aangegeven dat leerlingen eigenlijk drie talen zouden moeten leren. Deze norm wordt echter niet gehaald, omdat op de meeste scholen de instructietaal verschilt van de 'moedertaal' van docenten en leerlingen.

De nieuwe regering die in 1994 aantrad had de enorme taak de verschillende onderwijssystemen die onder de voormalige apartheidsregering bestonden samen te voegen. Aanvankelijk ging de meeste aandacht van het Ministerie van Onderwijs uit naar het ontmantelen van de structuren die onder apartheid waren ontstaan en naar het creëren van een rechtvaardiger basis voor de financiering van het onderwijs. Een veelheid aan beleidsdocumenten werd gepubliceerd, zoals het *White Paper, Education and Training in a Democratic South Africa: First Steps to Develop a New System* (February, 1995), de*National Education Policy Act (NEPA) (RSA, 1996),* de *South African Schools Act (SASA) (1996*), de *Further Education and Training Act (1998),* het *Education White Paper 4 on Further Education and Training (1998)* en de *National Strategy for Further Education and Training (1999-2001)*, de *Employment of Educators Act (RSA, 1998*), de *South African Qualifications Authority (SAQA) Act (RSA, 1995*) en het *Curriculum 2005 (C2005),* (DoE,1997a).

Sinds het aantreden van de nieuwe regering in 1994 is een omvangrijke onderwijshervorming in gang gezet waarbij een groot deel van de bevoegdheden in het onderwijs is overgeheveld naar de nieuwe provincies en deels ook naar de scholen. De hervormingsdoelen hadden betrekking op verbetering van toegang tot onderwijs, gelijke kansen op goed onderwijs, kwaliteit, efficiëntie en democratisering. De invoering van de *South African School Act* in 1996 had tot gevolg dat het grote aantal schooltypen ten tijde van de Apartheid werd teruggebracht tot twee: particuliere en openbare scholen. Bovendien werden 'zwarte' leerlingen aangemoedigd naar voormalige 'witte' scholen te gaan. Het verschil tussen rijke en arme scholen is evenwel nog steeds groot. Steeds zichtbaarder wordt dat de ongelijkheid toeneemt, nu niet zozeer langs raciale lijnen maar veeleer in termen van inkomen en welvaart.

Een nieuw curriculum (*Curriculum 2005*) werd beoogd voor de grades 1-9 (6-14 jarigen; zie ook 2.3). Aan de ontwikkeling ervan is door een groot aantal bij het onderwijs betrokkenen bijgedragen, in directe zin dan wel als adviseur. Het nieuwe curriculum werd in 1997 gepresenteerd (DoE, 1997a) met de bedoeling dat het in 2005 volledig zou zijn ingevoerd. Echter, medio 2002 is de implementatie van Curriculum 2005 nog steeds niet op gang gekomen, is het een aantal keren kritisch besproken en is het aan herziening onderhevig.

Een te gering aantal leerlingen in Zuid-Afrika kiest wiskunde als eindexamenvak en de meerderheid daarvan presteert ondermaats. Verschillende studies richtten zich op deze problematiek, maar over het algemeen zijn die studies kleinschalig en beperkt in omvang, en geen enkel onderzoek heeft zich gebaseerd op een representatieve steekproef van Zuid-Afrikaanse leerlingen zoals dat het geval was in TIMSS (1995) en TIMSS-R (1998). Om die reden komen deze twee studies tegemoet aan het gebrek aan betrouwbare en representatieve informatie op nationaal niveau over de prestaties van Zuid-Afrikaanse leerlingen in wiskunde en de natuurwetenschappelijke vakken.

Onderzoeksvragen en conceptueel raamwerk

De voorliggende studie beoogt een beschrijving te geven van de wiskundeprestaties en een aantal achtergrondgegevens van Zuid-Afrikaanse leerlingen in een internationaal vergelijkende context (eerste fase) en een exploratie van factoren die deze wiskundeprestaties beïnvloeden (tweede fase). De wiskundeprestaties die in deze studie zijn geanalyseerd, zijn gemeten in het kader van TIMSS-R (1998/1999). De eerste fase richt zich op het beschrijven van de prestaties van Zuid-Afrikaanse leerlingen op de TIMSS-R wiskundetoets en op een taalvaardigheidstoets voor Engels, alsook van achtergrondgegevens van leerlingen, leerkrachten en scholen, voor zover die zijn gemeten in TIMSS-R. Het doel van de tweede fase is te exploreren in hoeverre in TIMSS-R verzamelde achtergrondgegevens van leerlingen, leerkrachten en scholen samenhangen met de wiskundeprestaties en taalvaardigheid, en wat de onderlinge samenhang van die achtergrondgegevens is. Het conceptuele kader dat in deze studie is gebruikt voor de beantwoording van de onderzoeksvragen is gebaseerd op het conceptuele kader dat IEA voor zijn studies gebruikt en op het model ontwikkeld door Shavelson, McDonnell en Oakes (1987) (zie hoofdstuk 5).

De twee doelstellingen van het onderzoek zijn vertaald in de volgende onderzoeksvragen:

1. Wie zijn de leerlingen, leerkrachten en scholen die in TIMSS-R hebben deelgenomen?
2. Hoe hebben Zuid-Afrikaanse leerlingen gepresteerd op de TIMSS-R wiskundetoets?
3. Hoe zijn de prestaties van Zuid-Afrikaanse leerlingen in vergelijking met die van leerlingen uit andere landen?
4. Hoe zijn de prestaties van de Zuid-Afrikaanse leerlingen in 1998 (TIMSS-R) in vergelijking met de prestaties van de Zuid-Afrikaanse leerlingen in 1995 (TIMSS)?
5. Wat zijn de wiskundeprestaties van leerlingen uit de respectievelijke taalgroepen?
6. Hoe hebben leerlingen gepresteerd op de toets voor taalvaardigheid in Engels?
7. Op welke wijze en in welke mate komen leerlingen, voor wie Engels niet de moedertaal is, in aanraking met Engels?
8. Wat kan worden geleerd uit eerder onderzoek over factoren die samenhangen met prestaties voor wiskunde?
9. Wat kan worden geleerd van TIMSS-R over factoren die op school-, klas- en leerlingniveau samenhangen met prestaties voor wiskunde?

Onderzoeksopzet

Het voorliggende onderzoek bestaat vooral uit secundaire analyses van de Zuid-Afrikaanse TIMSS-R data. Dit houdt in dat deze studie zich beperkt tot het analyseren van data die zijn verzameld in het kader van de TIMSS-R studie. Aangezien de plannen voor dit onderzoek werden ontwikkeld in de tijd dat de onderzoeksopzet van TIMSS-R nog niet volledig was afgerond, was het nog mogelijk enkele nationale opties (op de Zuid-Afrikaanse context toegesneden onderdelen of vragen) toe te voegen. Gegeven de omvang van de dataverzameling voor de internationale component van de studie werd besloten slechts een beperkt aantal elementen aan de internationale instrumenten toe te voegen: een toets voor taalvaardigheid in Engels alsook een aantal vragen over de instructietaal in relatie tot de taal die thuis wordt gesproken.

SPSS (Statistical Package for the Social Sciences) is gebruikt voor de beschrijvende statistieken en de voorbereiding van de database voor de secondaire analyses. Vervolgens zijn Partial Least Square (PLS) analyses (met het pakket PLSpath 3.01) en multilevel analyses (met het pakket MlnwiN 1.10) gebruikt bij de beantwoording van onderzoeksvraag 9. Beide analyses hebben zekere beperkingen. PLS is geschikt voor exploratieve analyses, maar kan alleen worden gebruikt voor 'uni-level' analyses. Multilevel analyses kunnen worden gebruikt om data op meerdere niveaus te analyseren, maar deze techniek verschaft geen informatie over indirecte paden. Beide analysetechnieken kunnen als complementair worden gezien, waarbij de multilevel analyses konden voortbouwen op de resultaten uit de PLS analyses. Echter, ondanks deze complementariteit konden de analyses niet tot een nieuw model voor het verklaren van de wiskundeprestaties van Zuid-Afrikaanse leerlingen leiden., Een en ander is mede terug te voeren op het feit dat de studie zich baseerde op secundaire analyses van de TIMSS-R database. Een eigen onderzoeksdesign ontwikkelen vanuit de voorliggende onderzoeksvragen was niet mogelijk.

Belangrijkste resultaten

De belangrijkste resultaten uit de beschrijvende analyses van de gegevens van 194 Zuid-Afrikaanse scholen en 8.141 leerlingen zijn:

- Zuid-Afrikaanse leerlingen presteren significant slechter voor wiskunde (en ook voor de natuurwetenschappelijke vakken) dan leerlingen in alle andere deelnemende landen, inclusief andere ontwikkelingslanden.
- Er is geen significant verschil in de prestaties van Zuid-Afrikaanse leerlingen tussen 1998 en 1995.

- Zuid-Afrikaanse leerlingen hebben veel lagere scores op de open vragen (in vergelijking met de meerkeuzevragen) en hebben moeite met het formuleren van hun antwoorden.
- Leerlingen die thuis Engels of Afrikaans spreken, behalen hogere scores dan leerlingen die dat niet doen.
- De gemiddelde score op de taalvaardigheidtoets voor Engels is zeer laag en de taalvaardigheid van de meeste leerlingen is beperkt.
- Leerlingen in andere landen die de wiskundetoets ook in een andere taal dan hun moedertaal aflegden, behalen betere resultaten dan de beste Zuid-Afrikaanse leerlingen.
- Zuid-Afrikaanse leerlingen in grade 8 (te vergelijken met de 2e klas voortgezet onderwijs in Nederland) zijn gemiddeld ruim een jaar ouder dan de grade 8 leerlingen in andere landen (15,5 jaar versus 14,3 jaar).
- Meer dan tweederde van de leerlingen heeft thuis zeer weinig boeken (minder dan 10).
- Bijna een kwart van de wiskundeleraren is niet officieel bevoegd voor wiskunde en heeft na het voortgezet onderwijs geen verdere opleiding genoten.
- Zuid-Afrikaanse leerkrachten besteden aanzienlijk meer tijd aan het opnieuw behandelen van onderwerpen die in voorgaande leerjaren aan de orde zouden moeten zijn geweest dan hun collega's in de andere deelnemende landen.
- Zuid-Afrikaanse leerlingen van wie de leerkrachten zelf aangeven dat zij worden gewaardeerd in de samenleving alsook door hun leerlingen, behalen lagere resultaten voor wiskunde dan leerlingen van leerkrachten die aangeven dat dit niet het geval is.
- In vergelijking met andere landen in TIMSS-R zijn in Zuid-Afrika absentie van school en spijbelen hoog.

De secundaire analyse van de Zuid-Afrikaanse data (van 183 scholen en 7.651 leerlingen) resulteerde in de volgende bevindingen:

Op leerlingniveau:

- Taalvaardigheid in Engels is een zeer significante voorspeller van wiskundeprestatie waarbij taalvaardiger leerlingen hogere scores voor wiskunde behalen.
- Sociaal economische status (SES) heeft een significant effect op de wiskundeprestatie, waarbij leerlingen uit meer welvarende milieus hoger scoren voor wiskunde.

- Zuid-Afrikaanse leerlingen met een positief zelfbeeld voor wiskunde halen significant hogere scores op de wiskundetoets.
- Leerlingen van wie de moeder en vrienden aangeven dat wiskunde belangrijk is neigen naar significant hogere scores op de wiskundetoets.
- Hoe vaker leerlingen (via de radio) luisteren naar de taal van de toets (Engels of Afrikaans), des te hoger zijn hun prestaties voor wiskunde.
- Als uitsluitend factoren op leerlingniveau in de analyses worden betrokken, is 'moedertaal' (de taal die thuis wordt gesproken) een significante factor, maar deze significantie verdwijnt als bepaalde schoolfactoren in de analyses worden meegenomen.

Op schoolniveau:

- De locatie van de school is een significante predictor van wiskundeprestaties, waarbij leerlingen van scholen in steden in het algemeen hogere scores behalen.
- Instructietaal (de taal waarin wordt geleerd) is in Zuid-Afrika een significante voorspeller van leerlingprestaties, waarbij klassen waarvoor de instructietaal dezelfde is als de taal van de toets hogere scores haalden.
- Naarmate leerkrachten meer tijd besteden aan lesvoorbereiding, halen leerlingen hogere resultaten voor wiskunde.
- Pedagogische opvattingen van leerkrachten over het belang van wiskunde vormen in Zuid-Afrika een zeer significante voorspeller van wiskundeprestaties.
- Hoe minder leerkrachten zich voelen gewaardeerd (zowel maatschappelijk als door hun leerlingen), des te hoger zijn de toetsscores voor wiskunde.
- De tijd die leerkrachten in school doorbrengen is in Zuid-Afrika een zeer significante voorspeller van wiskundeprestaties van hun leerlingen.
- Klassegrootte heeft geen significante invloed op wiskundeprestaties wanneer alle andere factoren in ogenschouw zijn genomen.
- Onderwijslast is geen significante voorspeller van wiskundeprestaties wanneer alle andere factoren in ogenschouw zijn genomen.
- Schoolgrootte is geen significante voorspeller van wiskundeprestaties.

In de multilevel analyses werd meer dan de helft van de variantie in de wiskundescores gevonden op schoolniveau (55%), tegen 45% op leerlingniveau. Het eindmodel (zie Chapter 9) verklaarde 78% van de variantie op schoolniveau en slechts 50% van de variantie op leerlingniveau. Het belang van de factor 'taal' komt duidelijk naar voren, omdat een aantal taalvariabelen de wiskundeprestaties sterk beïnvloeden. Daarnaast zijn in Zuid-Afrika toewijding van de leerkracht en de locatie van de school belangrijke voorspellers van wiskundeprestaties.

Een niet-lineaire samenhang werd gevonden tussen de toetsscores voor taalvaardigheid in Engels en voor wiskunde. Dat wil zeggen dat de invloed van de factor taal sterker is naarmate de taalvaardigheid groter is. De grafiek (Figuur 9.2) laat ook zien dat er een aantal scholen is met een hoge score op de toets voor taalvaardigheid, terwijl de wiskunderesultaten laag zijn. Een mogelijke verklaring voor deze anomalie is dat het hier scholen betreft waar Engels de instructietaal is, maar waarin voor het onderzoek een klas met minder getalenteerde leerlingen is geselecteerd (hoewel 'tracking' meestal niet expliciet wordt toegepast, worden vooral voor wiskunde en natuurwetenschappelijke vakken leerlingen vaak in hoger respectievelijk lager presterende klassen ingedeeld).

Enkele hypothesen onderzocht

Hoewel deze studie vooral beschrijvend en exploratief van aard is, zijn toch enkele hypothesen geformuleerd op basis van de literatuur en de TIMSS-resultaten uit 1995.

De eerste hypothese hield in dat voor de wiskundeprestaties van Zuid-Afrikaanse leerlingen in grade 8 *factoren op schoolniveau een belangrijker rol zouden spelen dan factoren op leerlingniveau*. Uit het onderzoek blijkt dat een groter deel van de variantie in de wiskundescores kon worden verklaard op schoolniveau dan op leerlingniveau. Bovendien werden zes voorspellers van wiskundeprestaties gevonden op schoolniveau (hoewel het vooral factoren op klasniveau betrof) tegen vijf factoren op leerlingniveau. Recente resultaten van schooleffectiviteitsonderzoek laten echter zien dat factoren op schoolniveau veel minder invloed op leerprestaties hebben dan factoren op klasniveau. Deze resultaten konden niet worden geverifieerd in dit onderzoek, omdat per school slechts één klas aan het onderzoek heeft deelgenomen. Schoolniveau en klasniveau vielen daardoor in dit onderzoek samen. Omdat in het voorliggende onderzoek de meeste factoren op schoolniveau in feite factoren op klasniveau zijn, kan worden gesteld dat het onderzoek een zekere ondersteuning geeft voor de hypothese dat variabelen op klasniveau meer invloed hebben op leerlingpresaties dat factoren op leerlingniveau.

De tweede hypothese was dat *leerlingen die slecht presteren op de toets voor taalvaardigheid in Engels dat ook doen op de wiskundetoets*. De resultaten van het onderzoek ondersteunen deze hypothese. Omdat studies in enkele geïndustrialiseerde landen hebben aangetoond dat cognitieve vaardigheid de sterkste voorspeller is van presteren in wiskunde, zou een mogelijke verklaring voor het resultaat betreffende de tweede hypothese ook kunnen zijn dat de toets voor taalvaardigheid en de wiskundetoets beide beschouwd kunnen worden als een maat voor cognitieve vaardigheid. Omdat

TIMSS-R geen toets voor cognitieve vaardigheid bevat, kan dit vermoeden niet in het kader van deze studie worden onderzocht. Het is evenwel een onderwerp dat in de context van Zuid-Afrika nadere bestudering verdient.

Uit het beeld dat uit deze studie naar voren komt zou kunnen worden afgeleid dat Zuid-Afrikaanse leerkrachten in het algemeen te lage verwachtingen hebben van hun leerlingen en dat leerlingen zich tevreden stellen met wat zij weten en met wat van hen wordt gevraagd. Zuid-Afrikaanse leerlingen rapporteren dat zij wiskunde leuk vinden en dat zij vinden dat zij goed zijn in wiskunde. Daarnaast blijkt dat in Zuid-Afrika meer leerlingen aangeven dat zij wiskunde gemakkelijk vinden dan in hoog presterende landen als Japan en Korea, waar leerlingen het tegenovergestelde vinden. De academische standaard binnen veel Zuid-Afrikaanse scholen is laag en, gecombineerd met lage verwachtingen, resulteert dit in een schoolklimaat dat leerlingen onvoldoende uitdaagt. Het is aannemelijk dat deze situatie van lage standaarden en lage verwachtingen leidt tot de geflatteerde meningen van leerlingen over hun bekwaamheid en ook tot een lage motivatie die op haar beurt weer resulteert in het lager stellen van doelen. Mogelijkerwijs draagt de povere kwaliteit van beoordelingen en toetsen hier ook aan bij. Leertaken en toetsen zijn vaak cognitief onvoldoende uitdagend, terwijl de meerderheid van de leerkrachten zich richt op het niveau van de zwakste leerlingen. Deze situatie wordt nog verergerd door de onvoldoende wiskundekennis en het onvoldoende begrip van de aard van wiskunde als discipline bij veel leerkrachten, met een negatief effect op de kwaliteit van de instructie als gevolg. Dit tekort aan 'vakmanschap' werkt door in de wiskundelessen en leidt tot een *chalk and talk* wijze van lesgeven.

Tenslotte kan worden opgemerkt dat de resultaten over de samenhang tussen taalvaardigheid en wiskundeprestaties robuust zijn. Ze werden gevonden in alle analyses die in het kader van deze studie zijn uitgevoerd en bovendien bevestigen zij bevindingen van internationaal onderzoek. Wel kan worden gesteld dat de sterkte van de relatie tussen taalvariabelen en wiskundeprestaties sterker is dan uit veel ander onderzoek is gebleken, terwijl de niet-lineaire samenhang tussen vaardigheid in Engels en in wiskunde ook vermeldenswaard is. Deze uitkomsten konden alleen worden gevonden door het toepassen van technieken als PLS en MLN, omdat hoge correlatiecoëfficiënten wel aantonen dat er een relatie is tussen beide typen variabelen, maar geen inzicht geven in de aard en complexiteit van die relatie.

Conclusie

"Too many South African children are sentenced to restricted opportunities in life because their teachers and principals and district officials are incompetent or worse, or because their schools lack crucial facilities, or because there are no books or other learning materials" (Seekings, 2001, p. 187).

In Zuid-Afrika is de laatste jaren enige vooruitgang geboekt in het wegwerken van tekortkomingen in het onderwijs. Zo zijn er veel klaslokalen gebouwd waardoor het gemiddelde aantal leerlingen per klas daalde van 43 in 1996 tot 28 in 2000. Ook nam van 1996 tot 2000 het aantal scholen toe dat stromend water (+7%), elektriciteit (+15%) and telecommunicatie-faciliteiten (+25%) heeft. Daarentegen bleef het aantal scholen dat computers bezit en gebruikt voor leren en instructie laag (slechts 12% in 2000). Ook is de criminaliteit in scholen onacceptabel hoog: 36% van de scholen rapporteert kleine criminaliteit en 3% van de scholen rapporteert dat verkrachting, moord en geweldsmisdrijven voorkomen (SRN, 2000).

Hoewel in Zuid-Afrika in het onderwijs belangrijke vorderingen zijn geboekt op het terrein van administratieve hervormingen, beleidsontwikkelingen en infrastructurele hervormingen, is niettemin de kwaliteit van het onderwijs aan de meerderheid van de leerlingen ondermaats. Dit onderzoek heeft de belangrijkste voorspellers naar voren gehaald voor wiskundeprestaties in grade 8 van het Zuid-Afrikaanse onderwijs (voor zover mogelijk binnen de kaders van de TIMSS-R studie). Deze vormen de basis voor een aantal vragen en aandachtspunten waarvan mag worden aangenomen dat zij cruciaal zijn voor de toekomstige ontwikkeling van het Zuid-Afrikaanse onderwijs, in het bijzonder op het terrein van wiskunde. De belangrijkste uitdaging voor het onderwijs in Zuid-Afrika is, naast die van toegankelijkheid en gelijke kansen voor iedereen, die van de kwaliteit van het onderwijs. Wanneer het niveau van het onderwijs aan de meerderheid van de Zuid-Afrikaanse kinderen niet aanzienlijk wordt verbeterd en de verwachtingen over de prestaties van leerlingen bij de leerkrachten en de samenleving niet op een hoger niveau worden gebracht, zullen leerlingen blijven presteren op het huidige lage niveau. De vicieuze cirkel van pover presteren moet worden doorbroken door allereerst hogere verwachtingen te hebben van leerkrachten, van zowel hun professionaliteit als hun opleiding, culminerend in een stabiele, veilige en uitdagende school waarin geen plaats is voor incompetente schoolleiders en leerkrachten en voor niet-presterende leerlingen.

APPENDIX 1

Content of TIMSS-R questionnaires – student, mathematics teacher and school principal

Contents of the School Questionnaire

Question number	Content	Description
1	Community	Situates the school within a community of a specific type.
2-4	Staff	Describes the school's professional full and part-time staff and the percentage of teachers at the school for 5 or more years.
5	Years	Students stay with teacher indicates the number of years students typically stay with the same teacher.
6	Collaboration Policy	Identifies the existence of a school policy promoting teacher cooperation and collaboration.
7	Principal's Time	Indicates the amount of time the school's lead administrator typically spends on particular roles and functions.
8	School Decisions	Identifies who has the responsibility for various decisions for the school.
9	Curriculum Decisions	Identifies the amount of influence various individuals and educational and community groups have on curriculum decisions.
10	Formal Goals Statement	Formal Goals Statement indicates the existence of school-level curriculum goals for mathematics and science.
11-12	Instructional Resources.	Instructional Resources provides a description of the material factors limiting the school's instructional activities.
13	Students in the school	Students in the school provides total school enrollment and attendance data.
14	Students in the target grade	Students in the target grade Provides target grade enrollment and attendance data, student's enrollment in mathematics and science courses, and typical class sizes.
15	Number of Computers	Provides the number of computers for use by students in the target grade, by teachers, and in total.
16	Internet Access	Identifies whether the school has Internet access as well as identifying whether the school actively posts any school information on the world wide web.
17	Student Behaviors	Provides a description of the frequency with which schools encounter various unacceptable student behaviors.
18	Number of Computers	Provides the number of computers for use by students in the target grade, by teachers, and in total.

Contents of the School Questionnaire (*continued*)

19	Instructional Time	Instructional Time indicates the amount of instructional time scheduled for the target grade, according to the school's academic calendar.
20	Instructional Periods	Instructional Periods indicates the existence and length of weekly instructional periods for the target grade.
21	Organization of Mathematics Instruction (e.g., setting/streaming, tracking, and remedial/ enrichment programs)	Describes the school's provision for students with different ability levels in mathematics.
22	Program Decision Factors in Mathematics	Indicates how important various factors are in assigning students to different educational programs or tracks in mathematics.
23	Organization of Science Instruction (e.g., setting/ streaming, tracking, and remedial/enrichment programs)	Describes the school's provision for students with different ability levels in science.
24	Program Decision Factors in Science	Indicates how important various factors are in assigning students to different educational programs or tracks in science.
25	Admissions	Describes the basis on which students are admitted to the school.
26	Parental Involvement	Describes the kinds of activities in which parents are expected to participate (e.g., serve as teacher's aids, fundraising).

Source: Martin, Gregory & Stemler, 2000, Chapter 4.

Contents of the Teacher Questionnaires

Question number	Content	Description
1-2	Age and Sex	Identifies teacher's sex and age range.
3	Teaching Experience	Describes the teacher's number of years of teaching experience.
4-5	Instructional Time	Identifies the number of hours per week the teacher devotes to teaching mathematics, science, and other subjects.
6	Administrative Tasks	Identifies the number of hours per week spent on administrative tasks such as student supervision and counseling.
7	Other Teaching-Related Activities	Describes the amount of time teachers are involved in various professional responsibilities outside the formally-scheduled school day.
8	Teaching Activities	Describes the total number of hours per week spent on teaching activities.
9	Meet with Other Teachers	Describes the frequency with which teachers collaborate and consult with their colleagues.
10	Teacher's Influence	Describes the amount of influence that teachers perceive they have on various instructional decisions.
11	Being Good at Mathematics/Science	Describes teacher's beliefs about what skills are necessary for students to be good at mathematics/ science.
12	Ideas about Mathematics/ Science	Describes teacher's beliefs about the nature of mathematics/science and how the subject should be taught.
13	Document Familiarity	Describes teacher's knowledge of curriculum guides, teaching guides, and examination prescriptions (country-specific options).
14	Prepared to Teach Mathematics/Science Topics	Provides an indication of teacher's perceptions of their own preparedness to teach the TIMSS 1999 in-depth topic areas in mathematics or science.
15-18	Formal Education and Teacher Training	Describes the highest level of formal education completed by the teacher, the number of years of teacher training completed, and the teacher's major area of study.
19-20	Career Choices	Identifies whether teaching was a first choice and if the teacher would change careers if given the opportunity.
21	Social Appreciation	Describes whether teachers believe society appreciates their work.
22	Student Appreciation	Describes whether teachers believe students appreciates their work.
23	Books in Home	Provides an indicator of teacher's cultural capital.

Source: Martin, Gregory & Stemler, 2000, Chapter 4.

Contents of the student questionnaire

Question number	Content	Description
1-4	Student Demographics	Provides basic demographic information such as age, sex, language of the home, whether born in country and if not how long he/she has lived in country.
5	Academic Activities	Outside of School Provides information on student activities that can affect their academic achievement (e.g., extra lessons, science club).
6	Time Spent Outside of School	Provides information about the amount of time student spends on homework and leisure activities on a normal school day.
7	Parents' Education	Provides information about the educational level of the student's mother and father. Used as an indicator of the home environment and socioeconomic status.
8	Student's Future Educational Plans	Identifies the student's plans for further education.
9	Parents' Country of Birth	Provides information regarding immigrant status.
10	Books in the home	Provides information about the number of books in the home. Used as an indicator of the home environment and socioeconomic status.
11	Possessions in the home	Provides information about possessions found in the home (e.g., calculator, computer, study desk, country-specific items). Used as an indicator of academic support in the home environment as well as an indicator of socioeconomic status.
12	Mother's Values	Provides information about the student's perception of the degree of importance his/her mother places on academics and other activities. Used as an indicator of the home environ-ment and general academic press.
13	Student's Behavior in Mathematics Class	Provides a description of typical student behavior during mathematics lessons.
14	Peers' Values	Provides information about the student's perception of the degree of importance his/her peers place on academics and other activities. Used as an indicator of peers' values and student's social environment.
15	Student's Values	Provides information about the degree of importance the student places on academics and other activities. Used as an indicator of student's values.
16	Competence in Mathematics/Science	Provides an indication of student's self-description of academic competence in mathematics and science (specialized version asks about biology, earth science, chemistry, and physics separately).
17	Difficulty of Mathematics	Provides a description of student's perception of the difficulty level of mathematics.
18	Doing Well in Mathematics	Identifies student's attributions for doing well in mathematics.

Contents of the student questionnaire (*continued*)

Question number	Content	Description
19	Difficulty of Science	Provides a description of student's perception of the difficulty level of science (specialized version asks about biology, earth science, chemistry, and physics separately).
20	Doing Well in Science	Identifies student's attributions for doing well in science.
21	Liking Mathematics/ Science	Identifies how much students like mathematics and science; a key component of student motivation (specialized version asks about biology, earth science, chemistry, and physics separately).
22	Liking Computers for Mathematics/Science	Identifies how much students like using computers to learn mathematics and science.
23	Internet Access	Identifies whether students are accessing the Internet and for what purposes they are using it.
24	Interest, Importance, & Value of Mathematics	Provides a description of student's interest, importance rating, and value attributed to mathematics.
25	Reasons to Do Well in Mathematics	Provides the extent to which students endorse certain reasons they need to do well in mathematics.
26	Classroom Practices in Mathematics	Provides a description of student's perceptions of classroom practices in mathematics instruction.
27	Beginning a New Mathematics Topic	Describes the frequency with which specific strategies are used in the classroom to introduce a new mathematics topic.
28	Taking Science Class(es)	Identifies whether or not the student is enrolled in science classes this year (specialized version asks about biology, earth science, chemistry, and physics separately).
29	Interest, Importance, & Value of Science	Provides a description of student's interest, importance rating, and value attributed to science (specialized version asks about biology, earth science, chemistry, and physics separately).
30	Reasons to Do Well in Science	Provides the extent to which students endorse certain reasons they need to do well in science (specialized version asks about biology, earth science, chemistry, and physics separately).
31	Classroom Practices in Science	Provides a description of student's perceptions of classroom practices in science instruction (specialized version asks about biology, earth science, chemistry, and physics separately).
32	Beginning a New Science Topic	Describes the frequency with which specific strategies are used in the classroom to introduce a new science topic (specialized version asks about biology, earth science, chemistry, and physics separately).

Source: Martin, Gregory & Stemler, 2000, Chapter 4.

Contents of the student questionnaire

	International options	
33-34	People Living in the Home	Provides information about the home environment as an indicator of academic support and economic capital.
35-36 50-51 *why 50-51, and also below 52 etc?*	Cultural Activities	Provides a description of student's involvement in cultural events or programming such as plays or concerts.
37, 52	Report on Student Behaviors	Provides an indication of the student's perspective of the existence of specific problematic student behaviors at school.
38, 53	Environmental Issues	Provides and indication of student's beliefs about how much the application of science can help in addressing environmental issues.
39, 54	Science Use in a Career	Identifies preference for sciences in careers.

Source: Martin, Gregory & Stemler, 2000, Chapter 4.

APPENDIX 2
Copy of English test

WHICH UNDERLINED WORD IS SPELT ***WRONGLY?***

6. Lamplight and decorations (A) had transformed the schoolroom (B) from a prison to a banqueting hall. The long trestle-tables were patterned (C) with food; brown buns, cakes, ham-sanwiches (D).

7. Each of the guests (A) received (B) a balloon which they immediatly (C) blew up as large as possible (D).

8. Which word is spelt *wrongly*?

A. inspector B. instructor C. examinor D. visitor

9. Which underlined word needs an apostrophe (')?

I dont (A) know whether these mangoes (B) are ours (C) or yours (D).

10. Which underlined word or words are ***wrong***?

Perhaps in a few years' time every home will have (A) a clock that "lives on air". Such a clock has drawn (B) its energy from changes in the temperature. A change of one degree Celsius provides (C) enough power to keep (D) it going for two whole days!

WHICH WORD OR WORDS ***BEST*** COMPLETE THE SENTENCE?

11. After they had seen the film, they ... dinner.

A. were having
B. had had
C. have
D. had

12. If the car ... in time, an accident could have been avoided.

A. had stopped
B. stops
C. is stopping
D. stopping

13. Andrew ... down the motorway when a tyre burst.

    A. had raced
    B. was racing
    C. has raced
    D. races

14. Joan will leave as soon as she ... her ticket.

    A. had been buying
    B. been bought
    C. was buying
    D. has bought

15. After Tom ... the window he ran away.

    A. had broken
    B. breaks
    C. was breaking
    D. has broken

16. By the time you receive my letter I ...

    A. have left.
    B. shall have left.
    C. am leaving.
    D. left.

17. Peter: Have you seen John?
    Anne: No, I ...

    A. didn't. B. haven't. C. couldn't. D. shan't.

18. Which sentence is ***wrong***?

    A. The scissors <u>are</u> on the table.
    B. These trousers <u>are</u> too long.
    C. The news <u>are</u> good.
    D. People <u>are</u> allowed to use this exit.

19. WHICH IS THE ***CORRECT*** QUESTION FOR THE UNDERLINED STATEMENT?

    <u>The aeroplane arrives at ten o'clock</u>.

    A. When does the aeroplane arrive?
    B. When is the aeroplane arriving?
    C. When had the aeroplane arrived?
    D. When did the aeroplane arrive?

WHICH WORD OR WORDS *BEST* COMPLETE THE SENTENCE?

20. They asked the driver if he ... kindly stop the bus.

A. would B. had C. can D. may

21. In those days she ... nothing of getting up at five.

A. has thought
B. used to think
C. will think
D. ought to think

22. An apron ... round her neat blue dress.

A. is tied
B. was tying
C. has tying
D. was been tied

23. Which underlined word or words are ***wrong***?

> Plans to move the capital, Brasilia, were proposed (A) in 1822 but no progress was made (B) until 1956. Air photographs and ground surveys been used (C) to study the area. Climate, soil and water were considered (D).

24. Which is the ***best*** indirect form of the underlined sentence?

> The teacher said, "I am not satisfied with your work, Peter!". The teacher told Peter that ...
>
> A. he had not been satisfied with Peter's work.
> B. I was not satisfied with your work.
> C. I am not satisfied with his work.
> D. he was not satisfied with Peter's work.

25. Which underlined word is ***wrong?***

> Leopards? - Oom Schalk Lourens said - Oh, yes, there are two varieties on (A) this side of the Limpopo. But when you meet a leopard by (B) the veld unexpectedly, you seldom trouble to count his spots to find out (C) what kind he belongs to (D).

26. Which underlined word is *wrong*?

> So Bob got off (A) the bus, with sinking heart, at (B) the stop near the electric shop. He paused to look over (C) the window at a new TV that was on (D) show there.

WHICH WORD OR WORDS *BEST* COMPLETE THE SENTENCE?

27. The retired colonel ...

A. angrily wrote a letter to the editor.
B. wrote a letter angrily to the editor.
C. to the editor wrote a letter angrily.
D. to the editor wrote angrily a letter.

28. John threw ...

A. a ball to Peter.
B. to Peter a ball.
C. to Peter ball.
D. a ball Peter.

29. Which is the ***best*** combination of the underlined sentences?

He met with an accident. He was crossing the street.

A. He met with an accident because he was crossing the street.
B. While crossing the street, he met with an accident.
C. Although he was crossing the street, he met with an accident.
D. In order to cross the street he met with an accident.

30. Which word ***best*** completes the sentence?

The ... of that tall building took more than two years.

A. completes B. completion C. completed D. completeness

INDICATE WHETHER THE FOLLOWING SENTENCES ARE WRITTEN IN *GRAMMATICALLY ACCEPTABLE ENGLISH*.

A = RIGHT
B = WRONG

31. Since I came here I have attended many concerts.

A = RIGHT
B = WRONG

32. Mother gave the beggar a slice of bread and a cup of tea.

    A = RIGHT
    B = WRONG

33. Her car, what brakes never work, cost a fortune.

    A = RIGHT
    B = WRONG

34. Some problems seem less difficult than others.

    A = RIGHT
    B = WRONG

35. May I have some more salad, please?

    A = RIGHT
    B = WRONG

36. This room needs tidy.

    A = RIGHT
    B = WRONG

37. Their aunt, whose husband is a pilot, was once a teacher.

    A = RIGHT
    B = WRONG

38. For this recipe you need some flour, milk and eggs.

    A = RIGHT
    B = WRONG

39. Laws are making in Parliament.

    A = RIGHT
    B = WRONG

40. Let Bert lie down for a short rest.

    A = RIGHT
    B = WRONG

END OF SUBTEST 2

APPENDIX 3

Summary of language requirements and deficiencies in the English test

Language Test: some comments about the nature of the items

1. This item tests the writing skill of sequencing - coherence. L2 learners would find the word 'lodging' unfamiliar - that might throw them; also the notion of a 'respectable house' only getting going at 9am is very culture specific and outdated. It's not the kind of thing one would find in a modern text.

2. This also tests sequencing and coherence - this is a better text in terms of appropriateness, but of course it is still fairly remote from the experience of grade 8 learners.

3. The question is rather lengthy. It could cause difficulties for learners - examples of a fact and opinion might have been more helpful, given that many might not have been taught this by grade 8 although distinguishing between 'fact' and 'opinion' is something which is taught in language classes.

4. It is not clear as to whether learners would be familiar with telegram conventions - probably not from their own experience but it was part of the syllabus and maybe teachers are still teaching it and then it might not be such a difficult task. This would test concise accurate language use.

5. This requires a more subtle knowledge of language - tests just whether all the facts are included whereas the emphasis here is on the appropriate telegram style or register - so more difficult.

6. Questions 6, 7 and 8 obviously test spelling. It is supposed that this test was constructed for Afrikaans second language learners - whereas the majority in the TIMSS context were African language L2 learners. Perhaps commonly confused or misspelt words from an African language L2 context would have been a better indication of language ability.

9. Pretty straightforward grammar knowledge. Shouldn't have been too difficult - although many mistakes made with this in others experience.

10. More developed knowledge of tenses. Not so easy for learners as there is a switch from future tense to simple present at B - they cannot so easily guess from context at that point.

11 - 16. Testing knowledge of tenses - increasing difficulty.

17. B is correct but actually A or C would pass for perfectly understandable in ordinary speech.

18. This tests knowledge of plural nouns - should be fairly straightforward.

19. Again, the correct answer is A but B would also be perfectly okay in ordinary speech, so what is tested here is a detailed knowledge of grammar rather than communicative competence.

20-22. Test of correct verb usage which L2 learners should cope with.

23. This tests passive voice usage - which is particularly appropriate for science as that is typical of science texts.

24. Direct to indirect speech is a staple of L2 grammar lessons - nevertheless learners have problems doing it correctly. But this is fairly straightforward.

25. This seems to test a common error in preposition use made by Afrikaans L1 speakers.

26. Same as 25 but a more obvious error - and not specific to a language group.

27. Testing correct use of adverbs but actually B would also be perfectly okay in common usage.

28. Word order and use of prepositions and articles - should be quite easy.

29. 'Met with an accident' is a rather formal way of writing and might confuse learners - 'had an accident' would be the usual way of expression. And although B is the correct answer, A could equally be so. Testing knowledge of conjunctions.

30. Here the correct form of a noun formed from a verb is being tested - nominalisation of verbs is typical of academic and scientific texts.

31-40. Testing knowledge of grammar.

APPENDIX 4
Results of Student level Outer Model

SOUTH AFRICA TIMSS-R PLS STUDENT MODEL
Outer Model Results

Variable	**Weight**	**Loading**	**Commu-nality**	**Redun-dancy**	**Tolerance**
AGE	Outward	Exogen	1 MVs		
age_1	1.0000	1.0000	1.0000	.0000	.0000
ASPIRE	Outward	Endogen	1 MVs		
selfed_1	1.0000	1.0000	1.0000	.0227	.0000
LANG	Outward	Exogen	2 MVs		
Homelang	.5890	.8857	.7845	.0000	.2901
ralang_1	.5509	.8682	.7537	.0000	.2901
RACE	Outward	Exogen	1 MVs		
race_1	1.0000	1.0000	1.0000	.0000	.0000
HOME	Outward	Exogen	2 MVs		
famsize	.7758	.7940	.6305	.0000	.0009
parent	-.6081	-.6314	.3987	.0000	.0009
SES	Outward	Exogen	1 MVs		
posses10	1.0000	1.0000	1.0000	.0000	.0000
MATHIMPT	Outward	Endogen	1 MVs		
mathimp	1.0000	1.0000	1.0000	.0200	.0000
LANLEARN	Outward	Endogen	1 MVs		
lanlearn	1.0000	1.0000	1.0000	.2443	.0000
ATTEND	Outward	Endogen	1 MVs		
attend	1.0000	1.0000	1.0000	.0157	.0000
CLASSENV	Outward	Endogen	2 MVs		
quietcl	.5835	.8044	.6470	.0430	.1214
obedcl	.6338	.8371	.7008	.0466	.1214
SUCATTRB	Outward	Endogen	1 MVs		
luck	1.0000	1.0000	1.0000	.1019	.0000
ATTITUDE	Outward	Endogen	1 MVs		
borem_1	1.0000	1.0000	1.0000	.0317	.0000
SELFCNPT	Outward	Endogen	1 MVs		
difmath	1.0000	1.0000	1.0000	.1843	.0000
BOOK	Outward	Endogen	1 MVs		
books	1.0000	1.0000	1.0000	.1076	.0000
ENGTEST	Outward	Endogen	1 MVs		
totscore	1.0000	1.0000	1.0000	.3820	.0000
MATHSCR	Outward	Endogen	1 MVs		
bsmmat01	1.0000	1.0000	1.0000	.5025	.0000

APPENDIX 5
List of School-level factors

FACTORS	VARIABLES/ COMPOSITES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
Human resources	TEACHERS	bcbgftte bcggptte	the number of full-time teachers in the school, the number of part-time/full-time equivalent teachers in the school	Actual number Actual number
Selection of students	SCSELECT	Genbs02-3,7,10-12	admission procedures followed by the school to admit students	0. no 1. yes
Learning environment	ABSENT_1 CRIMEF MISDEMF	Bcbgabst Genuf01-18	percentage of students absent on an given day, the frequency of negative behaviour, and the	% of students 1. "never" 2. "rarely" 3. "monthly" 4. "weekly" 5. "daily"
	MISCRIME SERCRIME	Genus01-18	principal's perception of the gravity of this behaviour	1. "not a problem" 2. "minor problem" 3. "serious problem"
Principals' activities	ADMINISTRATION COMMUNICATION INSTRUCTIONAL LEADERSHIP TEACHING	Bcbgac01-04 Bcbgac09-11 Bcbgac07-08,12,13 Bcbgac05-06	the number of hours related to activities related to instructional leadership, communication, administration and communication	Number of hours per month
Parent	PAINV_1,-5,9-10	Genep01-05,9-10	schools' expectations of what parents should do at school	0. no 1. yes
First language	F_LANG	bsbghome	the number of students whose home language was the same as the medium of instruction in the school	1. African languages 2. English or Afrikaans
School	SCHSIZE	bcdgtenr	the number of students enrolled at the school	Actual number
Repeaters	REPEAT	bcdgutrt	the percentage of students repeating grade 8	Actual number
Class	CLASSIZE	bcbgusiz	the average number of students across the grade 8 classes)	Actual number

FACTORS	VARIABLES/ COMPOSITES	TIMSS-R VARIABLES	DESCRIPTION	SCORING
Time on task	SCHHOURS INSHOURS	Bcbguthw bcbguihw	Total hours of instruction Length of instructional period	Actual number Actual number
Grade	GRADSIZE	bcdguter	*Grade size* (the number of students in grade 8	Actual number
Community	SCCOMM_1	Schlcomm2	the location of the school: in isolated area or village rural town, outskirts of a city and city centre	1. geographically isolated area 2. village or rural (farm) area 3. on outskirts of town or city 4. close to centre of town or city
Retention staff	TEACH5-1	Bcbgte5y	the percentage of teachers who have been at the school for longer than 5 years	
Limitations	RESOURCM RESOURG	mathst_07-11,18 Genst01-05	shortages of general facilities and learning equipment, shortages of maths-related facilities and learning equipment	1. "none" 2. "a little" 3. "some" 4. "a lot"
Autonomy	DECISION	Genrp01-14	responsibility for taking decisions – outside school, school governing board, school, heads of departments and teachers.	1. not a school responsibility 2. school's governing board 3. "principal" 4. "department head" 5. teachers
	CURRICUL UNINF_15	Genif05-08 Genif15	The extent to which the staff at schools playing a role with regard to influencing the curriculum and specifically the role of teacher unions in influencing the curriculum implemented at the school	1. none 2. a little 3. some 4. a lot

APPENDIX 6
Results of School-level only Outer Model

SOUTH AFRICA TIMSS-R PLS SCHOOL MODEL
Outer Model Results

Variable	Weight	Loading	Commu-nality	Redun-dancy	Tolerance
COMMUNIT	Outward	Exogen	1 MVs		
sccomm_1	1.0000	1.0000	1.0000	.0000	.0000
UNION	Outward	Exogen	1 MVs		
uninf_15	1.0000	1.0000	1.0000	.0000	.0000
RESOURCE	Outward	Exogen	1 MVs		
resourcg	1.0000	1.0000	1.0000	.0000	.0000
FIRSLANG	Outward	Exogen	1 MVs		
f_lang	1.0000	1.0000	1.0000	.0000	.0000
TEACHRAT	Outward	Exogen	1 MVs		
tstratio	1.0000	1.0000	1.0000	.0000	.0000
REPEATER	Outward	Endogen	1 MVs		
repeat	1.0000	1.0000	1.0000	.6879	.0000
SCHOOL	Outward	Endogen	1 MVs		
schsize	1.0000	1.0000	1.0000	.2065	.0000
CLASS	Outward	Endogen	1 MVs		
classize	1.0000	1.0000	1.0000	.1149	.0000
MATH	Outward	Endogen	1 MVs		
bsmmat_1	1.0000	1.0000	1.0000	.6222	.0000

APPENDIX 7
Results of Classroom-level only Outer Model

SOUTH AFRICA TIMSS-R PLS TEACHER MODEL
Outer Model Results

Variable	**Weight**	**Loading**	**Commu-nality**	**Redun-dancy**	**Tolerance**
TLOAD	Outward	Exogen	2 MVs		
tottime	.6816	.8178	.6687	.0000	.0530
alltime	.5915	.7484	.5601	.0000	.0530
TBACKGR	Outward	Exogen	1 MVs		
bookhome	1.0000	1.0000	1.0000	.0000	.0000
GENDER	Outward	Exogen	1 MVs		
sexteach	1.0000	1.0000	1.0000	.0000	.0000
TEDUC	Outward	Exogen	1 MVs		
educatn	1.0000	1.0000	1.0000	.0000	.0000
EXPER	Outward	Exogen	1 MVs		
yrsteach	1.0000	1.0000	1.0000	.0000	.0000
RESOURCE	Outward	Exogen	1 MVs		
compoth	1.0000	1.0000	1.0000	.0000	.0000
CLASSIZE	Outward	Exogen	1 MVs		
testsize	1.0000	1.0000	1.0000	.0000	.0000
LIMIT	Outward	Exogen	2 MVs		
limstud	.5925	.8083	.6534	.0000	.1184
limteach	.6271	.8310	.6905	.0000	.1184
BELIEFS	Outward	Endogen	1 MVs		
tbmath	1.0000	1.0000	1.0000	.1223	.0000
ATTITUDE	Outward	Endogen	1 MVs		
apprec	1.0000	1.0000	1.0000	.3472	.0000
DEDIC	Outward	Endogen	1 MVs		
planlesn	1.0000	1.0000	1.0000	.0565	.0000
MATHSCR	Outward	Endogen	1 MVs		
clscore	1.0000	1.0000	1.0000	.4547	.0000
STSUCC	Outward	Endogen	1 MVs		
studsucc	1.0000	1.0000	1.0000	.0844	.0000
TSTYLE	Outward	Endogen	1 MVs		
pairclas	1.0000	1.0000	1.0000	.0963	.0000
ACTIV	Outward	Endogen	1 MVs		
teacact	1.0000	1.0000	1.0000	.1325	.0000

APPENDIX 8

Results of Combined school-level Outer Model

SOUTH AFRICA TIMSS-R PLS SCHOOL AND CLASS LEVEL MODEL
Outer Model Results

Variable	Weight	Loading	Communality	Redundancy	Tolerance
GENDER	Outward	Exogen	1 MVs		
sexteach	1.0000	1.0000	1.0000	.0000	.0000
AREA	Outward	Exogen	1 MVs		
sccomm_1	1.0000	1.0000	1.0000	.0000	.0000
AGGLANG	Outward	Exogen	1 MVs		
homela_1	1.0000	1.0000	1.0000	.0000	.0000
AGGSES	Outward	Exogen	1 MVs		
posses_1	1.0000	1.0000	1.0000	.0000	.0000
TLOAD	Outward	Endogen	2 MVs		
tottime	.6017	.7504	.5631	.0812	.0482
alltime	.6775	.8096	.6555	.0946	.0482
LIMITS	Outward	Endogen	1 MVs		
resourcg	1.0000	1.0000	1.0000	.0457	.0000
CLASSIZE	Outward	Endogen	1 MVs		
testsize	1.0000	1.0000	1.0000	.1101	.0000
BELIEFS	Outward	Endogen	1 MVs		
tbmath	1.0000	1.0000	1.0000	.2144	.0000
ATTITUDE	Outward	Endogen	1 MVs		
apprec	1.0000	1.0000	1.0000	.4122	.0000
AGGENG	Outward	Endogen	1 MVs		
totsco_1	1.0000	1.0000	1.0000	.6336	.0000
AGGSELFC	Outward	Endogen	1 MVs		
difmat_1	1.0000	1.0000	1.0000	.4895	.0000
DEDIC	Outward	Endogen	1 MVs		
planlesn	1.0000	1.0000	1.0000	.0907	.0000
MATHSCOR	Outward	Endogen	1 MVs		
bsmmat_1	1.0000	1.0000	1.0000	.4699	.0000
RESOURCE	Outward	Endogen	1 MVs		
compoth	1.0000	1.0000	1.0000	.0168	.0000

APPENDIX 9
Multilevel analysis Models 0-15

Fixed effect	Model 0		Model 1		Model 2		Model 3		Model 4		Model 5	
student level		SE		SE		SE		SE		SE		SE
intercept	288	6.04	275.9	6.54	266.7	6.88	269.2	5.55	321.2	5.86	279.4	6.48
hlang			8.79	2.22**	8.52	2.23**	5.84	2.13**	6.04	2.07**	6.51	2.04**
ses					1.64	0.47**	1.51	0.45**	1.43	0.44**	1.26	0.43**
engtest							4.90	0.19**	4.36	0.18**	4.10	0.18**
selfconp									-5.73	0.26**	-6.32	0.26**
impmath											6.40	0.45**
radiolg												
school level												
status												
mathphil												
location												
claslang												
enrolmt												
Worktim												
clsize												
planning												
teachtim												
Random effects												
school	6520 (55%)	696.7	5967 (8%)	641.3	5638 (14%)	606.6	2892 (56%)	316.9	2680 (59%)	294	2621 (60%)	286.7
student	5342 (45%)	587.42	5343 (5%)	87.43	5341 (7%)	87.4	4990 (34%)	81.66	4695 (38%)	76.83	4571 (39%)	74.81
Deviation			14.90		12.04		625.95		469.48		203.52	

Multilevel analysis of the South African data

Fixed effect	Model 5		Model 6		Model 7		Model 8		Model 9		Model 10	
student level		SE		SE		SE		SE		SE		SE
intercept	279.4	6.48	278.3	6.40	338.8	10.18	367.1	12.12	336.2	14.74	326.7	14.72
hlang	6.51	2.04**	5.35	2.07**	4.04	2.08	3.80	2.08	3.68	2.08	3.17	2.08
ses	1.27	0.43**	1.20	0.43**	1.11	0.43**	1.09	0.43*	0.96	0.43*	0.90	0.43*
engtest	4.10	0.18**	4.07	0.18**	4.03	0.18**	4.04	0.18**	4.01	0.18**	3.98	0.18**
selfconp	-6.32	0.26**	-6.32	0.26**	-6.31	0.26**	-6.31	0.26**	-6.30	0.26**	-6.30	0.26**
impmath	6.40	.45**	6.39	.45**	6.38	0.44**	6.39	0.44**	6.40	0.44**	6.37	0.44**
radiolg			4.75	1.23**	4.54	1.23**	4.46	1.23**	4.35	1.23**	4.03	1.23**
school level												
status					-36.27	4.64**	-28.35	4.79**	-24.81	4.77**	-23.8	4.70**
mathphil							-4.90	1.16**	-4.52	1.13**	-4.31	1.11**
location									12.24	3.55**	11.83	3.50**
claslang											2.62	0.69**
enrolmt												
Worktim												
clsize												
planning												
teachtim												
Random effects												
school	2621 (60%)	286.7	2451 (62%)	269.6	1838 (72%)	205.8	1669 (74%)	187.5	1579 (76%)	178.7	1520 (77%)	172.3
student	4571 (39%)	74.81	4570 (41%)	74.78	4566 (46%)	74.72	4566 (47%)	74.71	4564 (48%)	74.68	4559 (49%)	74.61
Deviation			14.59		55.40		17.30		11.70		14.53	

Multilevel analysis of the South African data

Fixed effect	Model 10		Model 11		Model 12		Model 13		Model 14		Model 15	
student level		SE		SE		SE		SEu		SE		SE
intercept	326.7	14.72	324.1	15.68	308.4	15.89	318.3	16.78	301.8	17.66	299.5	18.22
hlang	3.17	2.08	3.15	2.08	3.12	2.08	3.12	2.08	3.29	2.08	3.27	2.08
ses	0.90	0.43*	0.90	0.43*	0.87	0.43*	0.87	0.43*	0.88	0.43*	0.88	0.43*
engtest	3.98	0.18**	3.98	0.18**	3.99	0.18**	3.99	0.18**	4.00	0.18**	4.00	0.18**
selfconp	-6.30	0.26**	-6.30	0.26**	-6.30	0.26**	-6.30	0.26**	-6.29	0.26**	-6.29	0.26**
impmath	6.37	0.44**	6.37	0.44**	6.37	0.44**	6.37	0.44**	6.35	0.44**	6.35	0.44**
radiolg	4.03	1.23**	4.01	1.23**	4.03	1.23**	3.99	1.23**	3.96	1.23**	3.95	1.23**
school level												
status	-23.80	4.70**	-23.79	4.70**	-20.36	4.66**	-19.26	4.66**	-17.66	4.61**	-17.27	4.67**
mathphil	-4.31	1.11**	-4.23	1.13**	-4.63	1.10**	-4.47	1.09**	-4.46	1.07**	-4.46	1.07**
location	11.83	3.50**	11.09	3.83**	10.30	3.72*	9.06	3.75*	8.16	3.70*	8.00	3.71*
claslang	2.62	0.69**	2.62	0.69**	2.60	0.69**	2.59	0.69**	2.60	0.69**	2.59	0.69**
enrolmt			0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Worktim					0.58	0.17	0.60	0.17**	0.53	0.17**	0.52	0.17**
clsize							-0.27	0.16	-0.28	0.15	-0.27	0.15
planning									8.01	3.13*	8.02	3.13*
teachtim											0.10	0.20
school level												
Random effects												
school	1520 (77%)	172.3	1519 (77%)	171.6	1422 (78%)	162.5	1395 (79%)	158.9	1338 (79%)	153.3	1336 (79%)	152.5
student	4559 (49%)	74.61	4559 (49%)	74.61	4559 (50%)	74.6	4559 (50%)	74.61	4560 (50%)	74.61	4560 (50%)	74.62
Deviation			0.23		11.62		3.04		9.52		9.76	

Multilevel analysis of the South African data

Fixed effect	Model 15 Full Model		Model 16 *with random slopes*	
student level				
		SE		SE
intercept	299.5	18.22	285.5	15.45
hlang	3.27	2.08	2.83	2.08
ses	0.88	0.43*	0.79	0.43
engtest	4.00	0.18**	3.79	0.22**
selfconp	-6.29	0.26**	-6.20	0.26**
impmath	6.35	0.44**	6.45	0.44**
radiolg	3.95	1.23**	3.98	1.23**
school level				
status	-17.27	4.67**	-15.24	4.23**
mathphil	-4.46	1.07**	-3.68	0.89**
location	8.00	3.71*	7.07	3.09*
claslang	2.59	0.69**	2.55	0.68**
enrolmt	0.00	0.01	0.00	0.01
Worktim	0.52	0.17**	0.49	0.14**
clsize	-0.27	0.15	-0.14	0.12
planning	8.02	3.13*	7.16	2.62*
teachtim	0.10	0.20	0.14	0.17
school level				
Random effects				
school level variance (1)	1336 (79%)	152.5	1087	127.9
variance school averages				
engtest (2)	NA	NA	2.15	0.79
covariance (1) and (2)	NA	Na	38.25	7.71
student	4560 (50%)	74.62	4535	74.92
Deviation		46.26		

APPENDIX 10
Explained Proportion of Variance Models 0-15

Fixed effect	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
School level									
Variance	6 526 (55%)	5967	5638	2892	2680	2621	2451	1838	1669
Explained proportion of variance									
▪ When compared to Model 0	NA	.08	.14	.56	.59	.60	.62	.72	.74
▪ Due to last added variable	NA	.06	.06	.42	.03	.01	.02	.10	.02
Student level									
Variance	5 342 (45%)	5343	5341	4990	4695	4571	4570	4566	4566
Explained proportion of variance									.48
▪ When compared to Model 0	NA	.05	.07	.34	.38	.39	.41	.46	.47
▪ Due to last added variable	NA	.05	.02	.27	04	.05	.02	.05	.01

Note: The harmonic mean is applied by these calculations, harmonic mean = 1534.99; N/A = not applicable.

Model	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	
School level								
Variance	1579	1520	1519	1422	1395	1338	1336	
Explained proportion of variance								
▪ When compared to Model 0	.76	.77	.77	.78	.79	.79	.78	
▪ Due to last added variable	.01	.01	.00	.01	.02	.00	.00	
Student level								
Variance	4 564	4 559	4 559	4 559	4559	4560	4560	
Explained proportion of variance								
▪ When compared to Model 0	.48	.49	.49	.50	.50	.50	.50	
▪ Due to last added variable	.01	.01	.00	.01	.01	.00	.00	NA

Note: The harmonic mean is applied by these calculations, harmonic mean = 1534.99; N/A = not applicable.